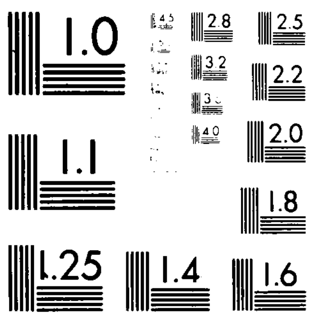
AD-A111 648 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/13
STRENGTH DESIGN OF REINFORCED CONCRETE HYDRAULIC STRUCTURES, RE--ETC(U)
DEC 81 T C LIU, S GLEASON
UNCLASSIFIED WES/TR/SL-80-4 NL

1 OF 3
AD
A111648



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963-A

AD A111648

12

TECHNICAL REPORT SL-80-4

STRENGTH DESIGN OF REINFORCED CONCRETE HYDRAULIC STRUCTURES

Report 2

DESIGN AIDS FOR USE IN THE DESIGN AND ANALYSIS OF REINFORCED CONCRETE HYDRAULIC STRUCTURAL MEMBERS SUBJECTED TO COMBINED FLEXURE AND AXIAL LOADS

by

Tony C. Liu and Scott Gleason
Structures Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

DTIC
ELECTE
MAR 4 1982
S A

December 1981

Report 2 of a Series

Approved For Public Release; Distribution Unlimited

DTIC FILE COPY

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under CWIS 31623

Destroy this report when no longer needed. Do not return it to the originator.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Technical Report SL-80-4	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) STRENGTH DESIGN OF REINFORCED CONCRETE HYDRAULIC STRUCTURES; Report 2, DESIGN AIDS FOR USE IN THE DESIGN AND ANALYSIS OF REINFORCED CONCRETE HYDRAULIC STRUCTURAL MEMBERS SUBJECTED TO COMBINED FLEXURE AND AXIAL LOADS		5. TYPE OF REPORT & PERIOD COVERED Report 2 of a series 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Tony C. Liu Scott Gleason		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Structures Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS CWIS 31623
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE December 1981 13. NUMBER OF PAGES 225
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Concrete strength	Loads (Forces)
Design data	Reinforced concrete
Hydraulic structures	
Load tests	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents design aids for use in the design and analysis of reinforced concrete hydraulic structural members subjected to combined uniaxial bending and axial loads.

A total of 190 load-moment strength interaction diagrams for both single and double reinforced members with various compressive strengths of concrete, yield strengths of steel reinforcement, reinforcement ratios, and concrete covers is included.

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

In addition to design aids, this report includes a commentary explaining how each design aid was calculated, and design examples illustrating the use of the design aids.

PREFACE

This report was prepared in the Structures Laboratory (SL), U. S. Army Engineer Waterways Experiment Station (WES), under the sponsorship of the Office, Chief of Engineers (OCE), U. S. Army, as a part of Civil Works Investigation Work Unit 31623. Mr. Donald R. Dressler of the Structures Branch, Engineering Division, OCE, served as technical monitor.

This work was conducted during the period October 1979 to September 1980 under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. John Scanlon, Chief, Concrete Technology Division, SL. This study was conducted and design aids were prepared by Dr. Tony C. Liu, SL, and Mr. Scott Gleason of the U. S. Army Engineer District, Tulsa.

The authors gratefully acknowledge the contributions of many individuals whose work is represented in this report. Particular thanks are due Mr. Roy Campbell of WES and Messrs. George Henson, Don Prentice, Ron Shurley, and Colleen Diven of the Tulsa District for development of the load-moment interaction diagrams and tables. The authors also wish to thank Mr. Dressler; Professor Phil M. Ferguson, University of Texas at Austin; Mr. Ervell A. Staab, Missouri River Division; Mr. Chester F. Berryhill, Southwestern Division; Mr. V. M. Agostinelli, Lower Mississippi Valley Division; Mr. Garland E. Young, Fort Worth District; Mr. Marion M. Harter, Kansas City District; and Dr. Paul Mlakar, Dr. N. Radhakrishnan, and Mr. William A. Price, WES, for their critical review of the manuscript.

The Commanders and Directors of the WES during this study and the preparation and publication of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. The Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, INCH-POUND TO METRIC (SI) UNITS OF MEASUREMENT

Inch-pound units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	25.4	millimetres
kips (force)	4448.222	newtons
kips (force) per foot	1459.3904	newtons per metre
kips (force) per inch	175126.8	newtons per metre
kips (force) per square foot	47.88026	kilopascals
kips (force) per square inch	6.894757	megapascals
kip (force)-feet	1355.818	newton-metres
kip (force)-inches	112.9848	newton-metres
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
square inches	6.4516	square centimetres

STRENGTH DESIGN OF REINFORCED CONCRETE HYDRAULIC STRUCTURES

DESIGN AIDS FOR USE IN THE DESIGN AND ANALYSIS OF REINFORCED CONCRETE HYDRAULIC STRUCTURAL MEMBERS SUBJECTED TO COMBINED FLEXURE AND AXIAL LOADS

PART I: INTRODUCTION

Purpose

1. This report is a presentation of design aids for use in the design and analysis of reinforced concrete hydraulic structural members subjected to combined uniaxial bending and axial loads. They are intended to save the designer the effort of performing certain routine, repetitious calculations.

2. These design aids are calculated in accordance with the strength design method developed in the second phase of this study,* which is a modification of the strength design method of the current "Building Code Requirements for Reinforced Concrete," ACI 318-77.** The notations used are the same as those used in ACI 318-77, except those defined in this report.

Scope

3. The load-moment strength interaction diagrams presented herein use: (a) nominal† axial stress P_N/bd rather than axial load, (b) an

---

* Tony C. Liu. "Strength Design of Reinforced Concrete Hydraulic Structures; T-Wall Design" (in preparation), Technical Report SL-80-4, Report 3, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

** American Concrete Institute. 1977. "Building Code Requirements for Reinforced Concrete," ACI 318-77, Detroit, Mich., hereinafter referred to as ACI 318-77.

† In this report subscript N means nominal; in ACI 318-77 and Reports 1 and 3 of this series the usage is n .

index of moment $P_N e/bd^2$ or M_N/bd^2 rather than moment itself, and (c) the reinforcement ratio. Thus, the load-moment strength interaction diagrams are not related to specific member sizes, loads, moments, or numbers and sizes of bars. The designer can determine the optimum design for a particular situation instead of merely selecting the member size and quantity and size of bars.

4. The basic design assumptions are as follows:

   a. Maximum usable strain ε_C at extreme concrete compression fiber should be assumed equal to 0.003. The allowable strain ε_M at extreme concrete compression fiber should be limited to $0.5\ \varepsilon_C$ for hydraulic structures.

   b. Balanced conditions exist at a cross section when the tension reinforcement reaches the strain corresponding to its specified yield strength f_y just as concrete in compression reaches its assumed allowable strain ε_M.

   c. Concrete stress of $0.85\ f'_c$ should be assumed uniformly distributed over an equivalent compression zone bounded by edges of the cross section and a straight line located parallel to the neutral axis at a distance $a = \beta_M C$ from the fiber of maximum compressive strain.

   d. Factor β_M should be taken as 0.55 for concrete strengths f'_c up to and including 4000 psi.* For strengths above 4000 psi, β_M should be reduced continuously at a rate of 0.05 for each 1000 psi of strength in excess of 4000 psi, but β_M should not be taken less than 0.50.

5. Design examples illustrating the use of the design aids are presented in the Part II. The design aids in the form of tables and diagrams are given in Part III.

6. An explanation of how each design aid was calculated is given in Appendix A.

---

* A table of factors for converting inch-pound units of measurement to metric (SI) units is presented on page 3.

PART II: DESIGN EXAMPLES

Example 1

7. Select the minimum effective depth d for a rectangular section subject to pure bending.

Given:

$$M_u = 1205.21 \text{ kip-in.}$$
$$f'_c = 3 \text{ ksi}$$
$$f_y = 40 \text{ ksi}$$
$$b = 12 \text{ in.}$$
$$\rho_{max} = 0.25\ \rho_b = 0.00928$$
$$\phi = 0.9$$

Procedure:

Step 1: Determine M_N .

$$M_N = \frac{M_u}{\phi}$$
$$= \frac{1205.21}{0.9} = 1339.12 \text{ kip-in.}$$

Step 2: Determine M_N/bd^2 and compute d .

Enter any interaction diagram for $f'_c = 3$ ksi, $f_y = 40$ ksi, and $\rho = 0.00928$ and read

$$\frac{M_N}{bd^2} = 0.348 \quad \text{at} \quad \frac{P_N}{bd} = 0$$

Then calculate d as follows:

$$d = \sqrt{\frac{M_N}{0.348b}}$$
$$= \sqrt{\frac{1339.12}{0.348 \times 12}} = 17.91 \text{ in.}$$
$$A_s = \rho bd$$
$$= 0.00928 \times 12 \times 17.91$$
$$= 1.994 \text{ in.}^2$$

USE: $d = 18$ in. and $A_s = 2.00 \text{ in.}^2$

Example 2

8. Determine the nominal moment strength M_N of a rectangular section subject to pure bending.

Given: $f'_c = 3$ ksi

$f_y = 40$ ksi

$b = 12$ in.

$d = 18$ in.

$A_s = 1.62$ in.^{2}

Procedure:

Step 1: Determine ρ .

$$\rho = \frac{A_s}{bd}$$

$$= \frac{1.62}{12 \times 18} = 0.0075$$

Step 2: Determine M_N/bd^2 using known values of variables on any interaction diagram.

Enter any interaction diagram for $f'_c = 3$ ksi, $f_y = 40$ ksi, and $\rho = 0.0075$ and read

$$\frac{M_N}{bd^2} = 0.282 \quad \text{at} \quad \frac{P_N}{bd} = 0$$

Therefore,

$$M_N = 0.282bd^2$$

$$= 0.282 \times 12 \times 18^2$$

$$= 1096.4 \text{ kip-in.}$$

Example 3

9. Select the member thickness h and reinforcement for a single

reinforced rectangular section subjected to combined flexure and compressive axial load.

Given:

M_u = 1368 kip-in.

P_u = 28.50 kips

f'_c = 3 ksi

f_y = 40 ksi

b = 12 in.

Concrete cover = 3 in.

Procedure:

1st Trial: h = 21 in. and No. 9 bars

Step 1.1: Determine h/d .

From Table 3, for 3-in. concrete cover and No. 9 bars, h/d = 1.20 for h = 21 in.

Step 1.2: Calculate ϕ .

$$\frac{P_u}{f'_c bh} = \frac{28.5}{3 \times 12 \times 21} = 0.0377$$

From Figure 1, $\phi = 0.82$ for

$$\frac{P_u}{f'_c bh} = 0.0377$$

Step 1.3: Calculate M_N/bd^2 and P_N/bd .

$$M_N = \frac{M_u}{\phi}$$

$$= \frac{1368}{0.82} = 1668.3 \text{ kip-in.}$$

$$P_N = \frac{P_u}{\phi}$$

$$= \frac{28.50}{0.82} = 34.8 \text{ kips}$$

For h/d = 1.20 , d = 21/1.20 = 17.5 in.

Therefore,

$$\frac{M_N}{bd^2} = \frac{1668.3}{12 \times 17.5 \times 17.5} = 0.454$$

$$\frac{P_N}{bd} = \frac{34.8}{12 \times 17.5} = 0.166$$

Step 1.4: Determine reinforcement ratio.

From Figure 4, for $M_N/bd^2 = 0.454$, $P_N/bd = 0.1657$, and $h/d = 1.20$, $\rho = 0.011$. Since this ρ value is greater than the maximum allowable value of $0.25\rho_b$ $(0.25\rho_b = 0.00928)$, a larger section is required.

2nd Trial: h = 22 in. and No. 9 bars

Step 2.1: Determine h/d.

From Table 3, for 3-in. concrete cover and No. 9 bars, $h/d = 1.19$.

Step 2.2: Calculate ϕ.

$$\frac{P_u}{f'_c bh} = \frac{28.5}{3 \times 12 \times 22} = 0.036$$

From Figure 1, $\phi = 0.83$ for $P_u/f'_c bh = 0.036$.

Step 2.3: Calculate M_N/bd^2 and P_N/bd.

$$M_N = \frac{1368}{0.83} = 1648.2 \text{ kip-in.}$$

$$P_N = \frac{28.50}{0.83} = 34.3 \text{ kips}$$

For $h/d = 1.19$, $d = 22/1.19 = 18.49$ in.

Therefore,

$$\frac{M_N}{bd^2} = \frac{1648.2}{12 \times 18.49 \times 18.49} = 0.402$$

$$\frac{P_N}{bd} = \frac{34.8}{12 \times 18.49} = 0.157$$

Step 2.4: Determine reinforcement ratio.

For $M_N/bd^2 = 0.402$ and $P_N/bd = 0.157$, from Figure 3,

$$\frac{h}{d} = 1.10 \qquad \rho = 0.0092$$

From Figure 4,

$$\frac{h}{d} = 1.20 \qquad \rho = 0.0090$$

By interpolation

$$\frac{h}{d} = 1.19 \qquad \rho = 0.00902 < 0.00928$$

USE: $h = 22$ in.

$A_s = 0.00902 \times 18.49 \times 12$

$= 2.00 \text{ in.}^2$

Two No. 9 bars will yield $A_s = 2.00 \text{ in.}^2$

Example 4

10. Determine reinforcement required for a double reinforced rectangular section subjected to combined flexure and compression.

Given:

$f'_c = 3000$ psi

$f_y = 40$ ksi

$b = 12$ in.

$h = 24$ in.

$M_u = 2160$ kip-in.

$P_u = 90$ kips

Concrete cover = 2 in.

Procedure:

Step 1: Assume values for d and d' .

Assume $d = 21.5$ in. and $d' = 2.5$ in. Therefore, $h/d = 1.116$ and $d'/d = 0.116$.

Step 2: Calculate ϕ .

$$\frac{P_u}{f'_c bh} = \frac{90}{3 \times 12 \times 24} = 0.104$$

From Figure 1, $\phi = 0.70$ for

$$\frac{P_u}{f'_c bh} = 0.104$$

Step 3: Calculate M_N/bd^2 and P_N/bd .

$$M_N = \frac{M_u}{\phi}$$

$$= \frac{2160}{0.70} = 3085.71 \text{ kip-in.}$$

$$P_N = \frac{P_u}{\phi}$$

$$= \frac{90}{0.70} = 128.57 \text{ kips}$$

$$\frac{M_N}{bd^2} = \frac{3085.71}{12 \times 21.5 \times 21.5} = 0.556$$

$$\frac{P_N}{bd} = \frac{128.57}{12 \times 21.5} = 0.498$$

Step 4: Determine reinforcement requirements.

1st Trial: Assume $\rho = 0.0075$.

For $f'_c = 3$ ksi, $f_y = 40$ ksi, $h/d = 1.10$, use Figure 44. From this figure, it can be found that the intersection of $M_N/bd^2 = 0.556$ and $P_N/bd = 0.498$ is outside of the interaction curves. This implies that the assumed $\rho = 0.0075$ is not sufficient.

2nd Trial: Assume $\rho = 0.0100$.

For $f'_c = 3$ ksi, $f_y = 40$ ksi, $h/d = 1.10$, use Figure 49. From Figure 49, for $M_N/bd^2 = 0.556$ and $P_N/bd = 0.498$, read $\rho' = 0.0050$. From Figure 50, for $h/d = 1.20$, $M_N/bd^2 = 0.556$, and $P_N/bd = 0.498$, read $\rho' = 0.0075$. By interpolation $\rho' = 0.0054$ for $h/d = 0.116$. Therefore,

$$A_s = \rho bd = 0.01 \times 12 \times 21.5 = 2.58 \text{ in.}^2$$
$$A'_s = \rho' bd = 0.0054 \times 12 \times 21.5 = 1.39 \text{ in.}^2$$

USE: Two No. 10 bars for A_s ($A_s = 2.54$ in.^{2}) and two No. 8 bars for A'_s ($A'_s = 1.58$ in.^{2})

The actual $d = 24 - 2 - \frac{1.27}{2}$

$$= 21.36 \text{ in.}$$

This is close to the assumed value of 21.5 in. This design is acceptable. No additional trial is necessary.

Example 5

11. Determine reinforcement requirement for a double reinforced rectangular section subjected to combined flexure and tension.

Given: $f'_c = 3000$ psi

$f_y = 48$ ksi

$$b = 12 \text{ in.}$$
$$h = 29 \text{ in.}$$
$$M_u = 317.62 \text{ kip-in.}$$
$$P_u = -222.26 \text{ kips}$$
$$\text{Concrete cover} = 4 \text{ in.}$$

Procedure:

Step 1: Assume $d = 24.5$ in. and $d' = 4.5$ in.

Therefore, $h/d = 1.18$ and $d'/d = 0.18$.

Step 2: Calculate M_N/bd^2 and P_N/bd .

Since P_u is in tension, use $\phi = 0.9$ and

$$P_N = \frac{P_u}{\phi} = \frac{-222.26}{0.9} = -246.96 \text{ kips}$$

$$M_N = \frac{M_u}{\phi} = \frac{317.62}{0.9} = 352.91 \text{ kip-in.}$$

$$\frac{P_N}{bd} = \frac{-246.96}{12 \times 24.5} = -0.84$$

$$\frac{M_N}{bd^2} = \frac{352.91}{12 \times 24.5 \times 24.5} = 0.049$$

Step 3: Determine reinforcement requirements.

1st Trial: Assume $\rho = 0.0100$.

From Figure 74, for $\rho = 0.0100$ and $h/d = 1.10$, the intersection of $M_N/bd^2 = 0.049$ and $P_N/bd = -0.84$ is at the intersection curve of $\rho' = 0.0075$. Similarly, from Figure 75, for $\rho = 0.0100$ and $h/d = 1.20$, read $\rho' = 0.0075$. Therefore, no interpolation is required for $h/d = 1.18$.

$$A_s = \rho bd = 0.010 \times 12 \times 24.5 = 2.94 \text{ in.}^2$$
$$A_s' = \rho' bd = 0.0075 \times 12 \times 24.5 = 2.205 \text{ in.}^2$$

USE: Three No. 9 bars for A_s ($A_s = 3.00$ in.^{2})
Two No. 8 bars and one No. 7 bar for A'_s
($A'_s = 2.18$ in.^{2})

The actual $d = 29 - 4 - \frac{1.128}{2}$

$= 24.43$ in.

This d value is close to the assumed value of 24.50 in. The design is acceptable.

Example 6

12. Determine the allowable factored moment strength for a double reinforced rectangular section.

Given: $f'_c = 3000$ psi
$f_y = 40$ ksi
$b = 12$ in.
$h = 24$ in.
$d = 20$ in.
$d' = 4$ in.
$A_s = 1.80$ in.^{2}
$A'_s = 1.20$ in.^{2}
$P_u = 311$ kips

Procedure:

Step 1: Determine h/d , ρ , and ρ' .

$$\frac{h}{d} = \frac{24}{20} = 1.20$$

$$\rho = \frac{1.80}{12 \times 20} = 0.0075$$

$$\rho' = \frac{1.20}{12 \times 20} = 0.0050$$

Step 2: Calculate ϕ .

$$\frac{P_u}{f'_c bh} = \frac{311}{3 \times 12 \times 24} = 0.36$$

From Figure 1, $\phi = 0.7$.

Step 3: Calculate P_N/bd .

$$P_N = \frac{P_u}{\phi} = \frac{311}{0.7} = 444.29 \text{ kips}$$

$$\frac{P_N}{bd} = \frac{444.29}{12 \times 20} = 1.85$$

From Figure 45 for $\rho = 0.0075$, $\rho' = 0.0050$, $P_N/bd = 1.85$, read $M_N/bd^2 = 0.51$

$$M_N = 0.51 \times 12 \times 20 \times 20$$

$$= 2448 \text{ kip-in.}$$

and

$$M_u = \phi M_N = 0.7 \times 2448$$

$$= 1713.6 \text{ kip-in.}$$

PART III: DESIGN AIDS

13. Tables 1-9 and Figures 1-193 are the design aids for use in the design and analysis of reinforced concrete hydraulic structural members subjected to combined uniaxial bending and axial loads.

Table 1

Values of h/d for 2.0-in. Concrete Cover

h (INCHES)	BAR SIZE #5	#6	#7	#8	#9	#10	#11	#14S	#18S
12.00	1.24	1.25	1.25	1.26	1.27	1.28	1.29	1.31	1.35
13.00	1.22	1.22	1.23	1.24	1.25	1.25	1.26	1.28	1.32
14.00	1.20	1.20	1.21	1.22	1.22	1.23	1.24	1.26	1.29
15.00	1.18	1.19	1.19	1.20	1.21	1.21	1.22	1.23	1.26
16.00	1.17	1.17	1.18	1.19	1.19	1.20	1.20	1.22	1.24
17.00	1.16	1.16	1.17	1.17	1.18	1.18	1.19	1.20	1.23
18.00	1.15	1.15	1.16	1.16	1.17	1.17	1.18	1.19	1.21
19.00	1.14	1.14	1.15	1.15	1.16	1.16	1.17	1.18	1.20
20.00	1.13	1.13	1.14	1.14	1.15	1.15	1.16	1.17	1.19
21.00	1.12	[illegible]	1.13	1.14	1.14	1.14	1.15	1.16	1.18
22.00	1.12	1.12	1.12	1.13	1.13	1.14	1.14	1.15	1.17
23.00	1.11	[illegible]	1.12	1.12	1.13	1.13	1.13	1.14	1.16
24.00	1.11	[illegible]	1.11	1.12	1.12	1.12	1.13	1.13	1.15
25.00	1.10	[illegible]	1.11	1.11	1.11	1.12	1.12	1.13	1.14
26.00	1.10	[illegible]	1.10	1.11	1.11	1.11	1.12	1.12	1.14
27.00	1.09	1.10	1.10	1.10	1.10	1.11	1.11	1.12	1.13
28.00	1.09	1.09	1.10	1.10	1.10	1.10	1.11	1.11	1.13
29.00	1.09	1.09	1.09	1.09	1.10	1.10	1.10	1.11	1.12
30.00	1.08	1.09	1.09	1.09	1.09	1.10	1.10	1.10	1.12
32.00	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.10	1.11
34.00	1.07	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.10
36.00	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.09	1.10
38.00	1.06	1.07	1.07	1.07	1.07	1.07	1.08	1.08	1.09
40.00	1.06	1.06	1.06	1.07	1.07	1.07	1.07	1.08	1.08
42.00	1.06	1.06	1.06	1.06	1.07	1.07	1.07	1.07	1.08
44.00	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.07	1.08
46.00	1.05	1.05	1.06	1.06	1.06	1.06	1.06	1.07	1.07
48.00	1.05	1.05	1.05	1.05	1.06	1.06	1.06	1.06	1.07
50.00	1.05	1.05	1.05	1.05	1.05	1.06	1.06	1.06	1.07
52.00	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.06	1.06
54.00	1.04	1.05	1.05	1.05	1.05	1.05	1.05	1.06	1.06
56.00	1.04	1.04	1.05	1.05	1.05	1.05	1.05	1.05	1.06
58.00	1.04	1.04	1.04	1.05	1.05	1.05	1.05	1.05	1.06
60.00	1.04	1.04	1.04	1.04	1.04	1.05	1.05	1.05	1.06
62.00	1.04	1.04	1.04	1.04	1.04	1.04	1.05	1.05	1.05
64.00	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.05	1.05
66.00	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.05	1.05
68.00	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.05
70.00	1.03	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.05
72.00	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.04	1.05

Table 2

Values of h/d for 2.5-in. Concrete Cover

h (INCHES)	BAR SIZE #5	#6	#7	#8	#9	#10	#11	#14S	#18S
12.00	1.31	1.32	1.32	1.33	1.34	1.35	1.36	1.39	1.42
13.00	1.28	1.28	1.29	1.30	1.31	1.32	1.33	1.35	1.39
14.00	1.25	1.26	1.27	1.27	1.28	1.29	1.30	1.31	1.35
15.00	1.23	1.24	1.24	1.25	1.26	1.26	1.27	1.29	1.32
16.00	1.21	1.22	1.22	1.23	1.24	1.24	1.25	1.26	1.29
17.00	1.20	1.20	1.21	1.21	1.22	1.23	1.23	1.25	1.27
18.00	1.19	1.19	1.20	1.20	1.21	1.21	1.22	1.23	1.25
19.00	1.17	1.18	1.18	1.19	1.19	1.20	1.20	1.21	1.24
20.00	1.16	1.17	1.17	1.18	1.18	1.19	1.19	1.20	1.22
21.00	1.15	1.16	1.16	1.17	1.17	1.18	1.18	1.19	1.21
22.00	1.15	1.15	1.15	1.16	1.16	1.17	1.17	1.18	1.20
23.00	1.14	1.14	1.15	1.15	1.15	1.16	1.16	1.17	1.19
24.00	1.13	1.14	1.14	1.14	1.15	1.15	1.15	1.16	1.18
25.00	1.13	1.13	1.13	1.14	1.14	1.14	1.15	1.15	1.17
26.00	1.12	1.12	1.13	1.13	1.13	1.14	1.14	1.15	1.16
27.00	1.12	1.12	1.12	1.13	1.13	1.13	1.13	1.14	1.16
28.00	1.11	1.11	1.12	1.12	1.12	1.13	1.13	1.14	1.15
29.00	1.11	1.11	1.11	1.12	1.12	1.12	1.12	1.13	1.14
30.00	1.10	1.11	1.11	1.11	1.11	1.12	1.12	1.13	1.14
32.00	1.10	1.10	1.10	1.10	1.11	1.11	1.11	1.12	1.13
34.00	1.09	1.09	1.09	1.10	1.10	1.10	1.10	1.11	1.12
36.00	1.08	1.09	1.09	1.09	1.09	1.10	1.10	1.10	1.11
38.00	1.08	1.08	1.08	1.09	1.09	1.09	1.09	1.10	1.11
40.00	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.10
42.00	1.07	1.07	1.08	1.08	1.08	1.08	1.08	1.09	1.09
44.00	1.07	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.09
46.00	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.08	1.09
48.00	1.06	1.06	1.07	1.07	1.07	1.07	1.07	1.07	1.08
50.00	1.06	1.06	1.06	1.06	1.07	1.07	1.07	1.07	1.08
52.00	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.07	1.08
54.00	1.05	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.07
56.00	1.05	1.05	1.06	1.06	1.06	1.06	1.06	1.06	1.07
58.00	1.05	1.05	1.05	1.05	1.06	1.06	1.06	1.06	1.07
60.00	1.05	1.05	1.05	1.05	1.05	1.06	1.06	1.06	1.06
62.00	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.06	1.06
64.00	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.06	1.06
66.00	1.04	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.06
68.00	1.04	1.04	1.05	1.05	1.05	1.05	1.05	1.05	1.06
70.00	1.04	1.04	1.04	1.04	1.05	1.05	1.05	1.05	1.05
72.00	1.04	1.04	1.04	1.04	1.04	1.05	1.05	1.05	1.05

Table 3

Values of h/d for 3.0-in. Concrete Cover

h (INCHES)	BAR SIZE #5	#6	#7	#8	#9	#10	#11	#14S	#18S
12.00	1.38	1.39	1.40	1.41	1.42	1.43	1.45	1.47	1.52
13.00	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.42	1.47
14.00	1.31	1.32	1.33	1.33	1.34	1.35	1.36	1.38	1.42
15.00	1.28	1.29	1.30	1.30	1.31	1.32	1.33	1.34	1.38
16.00	1.26	1.27	1.27	1.28	1.29	1.29	1.30	1.32	1.35
17.00	1.24	1.25	1.25	1.26	1.27	1.27	1.28	1.29	1.32
18.00	1.23	1.23	1.24	1.24	1.25	1.25	1.26	1.27	1.30
19.00	1.21	1.22	1.22	1.23	1.23	1.24	1.24	1.25	1.28
20.00	1.20	1.20	1.21	1.21	1.22	1.22	1.23	1.24	1.26
21.00	1.19	1.19	1.20	1.20	1.20	1.21	1.21	1.22	1.24
22.00	1.18	1.18	1.19	1.19	1.19	1.20	1.20	1.21	1.23
23.00	1.17	1.17	1.18	1.18	1.18	1.19	1.19	1.20	1.22
24.00	1.16	1.16	1.17	1.17	1.17	1.18	1.18	1.19	1.21
25.00	1.15	1.16	1.16	1.16	1.17	1.17	1.17	1.18	1.20
26.00	1.15	1.15	1.15	1.16	1.16	1.16	1.17	1.17	1.19
27.00	1.14	1.14	1.15	1.15	1.15	1.16	1.16	1.17	1.18
28.00	1.13	1.14	1.14	1.14	1.15	1.15	1.15	1.16	1.17
29.00	1.13	1.13	1.13	1.14	1.14	1.14	1.15	1.15	1.17
30.00	1.12	1.13	1.13	1.13	1.13	1.14	1.14	1.15	1.16
32.00	1.12	1.12	1.12	1.12	1.13	1.13	1.13	1.14	1.15
34.00	1.11	1.11	1.11	1.11	1.12	1.12	1.12	1.13	1.14
36.00	1.10	1.10	1.11	1.11	1.11	1.11	1.11	1.12	1.13
38.00	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11	1.12
40.00	1.09	1.09	1.09	1.10	1.10	1.10	1.10	1.11	1.12
42.00	1.09	1.09	1.09	1.09	1.09	1.09	1.10	1.10	1.11
44.00	1.08	1.08	1.08	1.09	1.09	1.09	1.09	1.10	1.10
46.00	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.10
48.00	1.07	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09
50.00	1.07	1.07	1.07	1.08	1.08	1.08	1.08	1.08	1.09
52.00	1.07	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.09
54.00	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.08	1.08
56.00	1.06	1.06	1.07	1.07	1.07	1.07	1.07	1.07	1.08
58.00	1.06	1.06	1.06	1.06	1.07	1.07	1.07	1.07	1.08
60.00	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.07	1.07
62.00	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.07
64.00	1.05	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.07
66.00	1.05	1.05	1.05	1.06	1.06	1.06	1.06	1.06	1.07
68.00	1.05	1.05	1.05	1.05	1.06	1.06	1.06	1.06	1.06
70.00	1.05	1.05	1.05	1.05	1.05	1.05	1.06	1.06	1.06
72.00	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.06	1.06

Table 4

<u>Values of h/d for 3.5-in. Concrete Cover</u>

h (INCHES)	BAR SIZE #5	#6	#7	#8	#9	#10	#11	#14S	#18S
12.00	1.47	1.48	1.49	1.50	1.51	1.53	1.54	1.57	1.6[illegible]
13.00	1.41	1.42	1.43	1.44	1.45	1.47	1.48	1.50	1.55
14.00	1.37	1.38	1.39	1.40	1.41	1.42	1.43	1.45	1.49
15.00	1.34	1.35	1.36	1.36	1.37	1.38	1.39	1.41	1.45
16.00	1.31	1.32	1.33	1.33	1.34	1.35	1.36	1.37	1.41
17.00	1.29	1.30	1.30	1.31	1.31	1.32	1.33	1.34	1.37
18.00	1.27	1.27	1.28	1.29	1.29	1.30	1.30	1.32	1.35
19.00	1.25	1.26	1.26	1.27	1.27	1.28	1.28	1.30	1.32
20.00	1.24	1.24	1.25	1.25	1.26	1.26	1.27	1.28	1.30
21.00	1.22	1.23	1.23	1.24	1.24	1.25	1.25	1.26	1.28
22.00	1.21	1.21	1.22	1.22	1.23	1.23	1.24	1.25	1.27
23.00	1.20	1.20	1.21	1.21	1.21	1.22	1.22	1.23	1.25
24.00	1.19	1.19	1.20	1.20	1.20	1.21	1.21	1.22	1.24
25.00	1.18	1.18	1.19	1.19	1.19	1.20	1.20	1.21	1.23
26.00	1.17	1.18	1.18	1.18	1.19	1.19	1.19	1.20	1.22
27.00	1.16	1.17	1.17	1.17	1.18	1.18	1.18	1.19	1.21
28.00	1.16	1.16	1.16	1.17	1.17	1.17	1.18	1.18	1.20
29.00	1.15	1.15	1.16	1.16	1.16	1.17	1.17	1.18	1.19
30.00	1.15	1.15	1.15	1.15	1.16	1.16	1.16	1.17	1.18
32.00	1.14	1.14	1.14	1.14	1.15	1.15	1.15	1.16	1.17
34.00	1.13	1.13	1.13	1.13	1.14	1.14	1.14	1.15	1.16
36.00	1.12	1.12	1.12	1.13	1.13	1.13	1.13	1.14	1.15
38.00	1.11	1.11	1.12	1.12	1.12	1.12	1.12	1.13	1.14
40.00	1.11	1.11	1.11	1.11	1.11	1.12	1.12	1.12	1.13
42.00	1.10	1.10	1.10	1.11	1.11	1.11	1.11	1.12	1.12
44.00	1.09	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.12
46.00	1.09	1.09	1.09	1.10	1.10	1.10	1.10	1.10	1.11
48.00	1.09	1.09	1.09	1.09	1.09	1.09	1.10	1.10	1.11
50.00	1.08	1.08	1.09	1.09	1.09	1.09	1.09	1.10	1.10
52.00	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.10
54.00	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09
56.00	1.07	1.07	1.08	1.08	1.08	1.08	1.08	1.08	1.09
58.00	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.08	1.09
60.00	1.07	1.07	1.07	1.07	1.07	1.07	1.08	1.08	1.08
62.00	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.08	1.08
64.00	1.06	1.06	1.07	1.07	1.07	1.07	1.07	1.07	1.08
66.00	1.06	1.06	1.06	1.06	1.07	1.07	1.07	1.07	1.08
68.00	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.07	1.07
70.00	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.07
72.00	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.07

Table 5

<u>Values of h/d for 4.0-in. Concrete Cover</u>

h (INCHES)	#5	#6	#7	#8	#9	#10	#11	#14S	#18S
	BAR SIZE								
14.00	1.45	1.45	1.46	1.47	1.48	1.49	1.51	1.53	1.58
15.00	1.40	1.41	1.42	1.43	1.44	1.45	1.46	1.48	1.52
16.00	1.37	1.38	1.38	1.39	1.40	1.41	1.42	1.43	1.47
17.00	1.34	1.35	1.35	1.36	1.37	1.37	1.38	1.40	1.43
18.00	1.32	1.32	1.33	1.33	1.34	1.35	1.35	1.37	1.40
19.00	1.29	1.30	1.30	1.31	1.32	1.32	1.33	1.34	1.37
20.00	1.27	1.28	1.29	1.29	1.30	1.30	1.31	1.32	1.34
21.00	1.26	1.26	1.27	1.27	1.28	1.28	1.29	1.30	1.32
22.00	1.24	1.25	1.25	1.26	1.26	1.27	1.27	1.28	1.30
23.00	1.23	1.23	1.24	1.24	1.25	1.25	1.26	1.27	1.29
24.00	1.22	1.22	1.23	1.23	1.23	1.24	1.24	1.25	1.27
25.00	1.21	1.21	1.22	1.22	1.22	1.23	1.23	1.24	1.26
26.00	1.20	1.20	1.21	1.21	1.21	1.22	1.22	1.23	1.25
27.00	1.19	1.19	1.20	1.20	1.20	1.21	1.21	1.22	1.23
28.00	1.18	1.19	1.19	1.19	1.19	1.20	1.20	1.21	1.22
29.00	1.17	1.18	1.18	1.18	1.19	1.19	1.19	1.20	1.21
30.00	1.17	1.17	1.17	1.18	1.18	1.18	1.19	1.19	1.21
32.00	1.16	1.16	1.16	1.16	1.17	1.17	1.17	1.18	1.19
34.00	1.15	1.15	1.15	1.15	1.16	1.16	1.16	1.17	1.18
36.00	1.14	1.14	1.14	1.14	1.15	1.15	1.15	1.16	1.17
38.00	1.13	1.13	1.13	1.13	1.14	1.14	1.14	1.15	1.16
40.00	1.12	1.12	1.12	1.13	1.13	1.13	1.13	1.14	1.15
42.00	1.11	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.14
44.00	1.11	1.11	1.11	1.11	1.12	1.12	1.12	1.12	1.13
46.00	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.12	1.13
48.00	1.10	1.10	1.10	1.10	1.11	1.11	1.11	1.11	1.12
50.00	1.09	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11
52.00	1.09	1.09	1.09	1.09	1.10	1.10	1.10	1.10	1.11
54.00	1.09	1.09	1.09	1.09	1.09	1.09	1.10	1.10	1.10
56.00	1.08	1.08	1.09	1.09	1.09	1.09	1.09	1.09	1.10
58.00	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.09	1.10
60.00	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09
62.00	1.07	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.09
64.00	1.07	1.07	1.07	1.08	1.08	1.08	1.08	1.08	1.09
66.00	1.07	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.08
68.00	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.08	1.08
70.00	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.08
72.00	1.06	1.06	1.07	1.07	1.07	1.07	1.07	1.07	1.08

Table 6

Values of h/d for 4.5-in. Concrete Cover

h (INCHES)	BAR SIZE #5	#6	#7	#8	#9	#10	#11	#14S	#18S
16.00	1.43	1.44	1.45	1.45	1.46	1.47	1.48	1.50	1.54
17.00	1.39	1.40	1.41	1.42	1.42	1.43	1.44	1.46	1.49
18.00	1.36	1.37	1.38	1.38	1.39	1.40	1.41	1.42	1.45
19.00	1.34	1.35	1.35	1.36	1.36	1.37	1.38	1.39	1.42
20.00	1.32	1.32	1.33	1.33	1.34	1.35	1.35	1.36	1.39
21.00	1.30	1.30	1.31	1.31	1.32	1.32	1.33	1.34	1.37
22.00	1.28	1.28	1.29	1.29	1.30	1.30	1.31	1.32	1.34
23.00	1.26	1.27	1.27	1.28	1.28	1.29	1.29	1.30	1.32
24.00	1.25	1.25	1.26	1.26	1.27	1.27	1.28	1.29	1.31
25.00	1.24	1.24	1.25	1.25	1.25	1.26	1.26	1.27	1.29
26.00	1.23	1.23	1.23	1.24	1.24	1.25	1.25	1.26	1.28
27.00	1.22	1.22	1.22	1.23	1.23	1.23	1.24	1.25	1.26
28.00	1.21	1.21	1.21	1.22	1.22	1.22	1.23	1.24	1.25
29.00	1.20	1.20	1.21	1.21	1.21	1.22	1.22	1.23	1.24
30.00	1.19	1.19	1.20	1.20	1.20	1.21	1.21	1.22	1.23
32.00	1.18	1.18	1.18	1.19	1.19	1.19	1.19	1.20	1.21
34.00	1.16	1.17	1.17	1.17	1.18	1.18	1.18	1.19	1.20
36.00	1.15	1.16	1.16	1.16	1.16	1.17	1.17	1.17	1.19
38.00	1.15	1.15	1.15	1.15	1.15	1.16	1.16	1.16	1.17
40.00	1.14	1.14	1.14	1.14	1.14	1.15	1.15	1.15	1.16
42.00	1.13	1.13	1.13	1.14	1.14	1.14	1.14	1.15	1.15
44.00	1.12	1.12	1.13	1.13	1.13	1.13	1.13	1.14	1.15
46.00	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.13	1.14
48.00	1.11	1.11	1.11	1.12	1.12	1.12	1.12	1.13	1.13
50.00	1.11	1.11	1.11	1.11	1.11	1.11	1.12	1.12	1.13
52.00	1.10	1.10	1.10	1.11	1.11	1.11	1.11	1.11	1.12
54.00	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11	1.12
56.00	1.09	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11
58.00	1.09	1.09	1.09	1.09	1.10	1.10	1.10	1.10	1.11
60.00	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.10	1.10
62.00	1.08	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.10
64.00	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.09	1.10
66.00	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09
68.00	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09
70.00	1.07	1.07	1.08	1.08	1.08	1.08	1.08	1.08	1.09
72.00	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.08	1.08

Table 7

Values of h/d for 5.0-in. Concrete Cover

h (INCHES)	BAR SIZE #5	#6	#7	#8	#9	#10	#11	#14S	#18S
16.00	1.50	1.51	1.51	1.52	1.53	1.54	1.55	1.58	1.62
17.00	1.45	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.56
18.00	1.42	1.43	1.43	1.44	1.45	1.46	1.46	1.48	1.52
19.00	1.39	1.39	1.40	1.41	1.41	1.42	1.43	1.44	1.48
20.00	1.36	1.37	1.37	1.38	1.39	1.39	1.40	1.41	1.44
21.00	1.34	1.34	1.35	1.35	1.36	1.37	1.37	1.39	1.41
22.00	1.32	1.32	1.33	1.33	1.34	1.34	1.35	1.36	1.39
23.00	1.30	1.30	1.31	1.31	1.32	1.32	1.33	1.34	1.36
24.00	1.28	1.29	1.29	1.30	1.30	1.31	1.31	1.32	1.34
25.00	1.27	1.27	1.28	1.28	1.29	1.29	1.30	1.31	1.32
26.00	1.26	1.26	1.26	1.27	1.27	1.28	1.28	1.29	1.31
27.00	1.24	1.25	1.25	1.26	1.26	1.26	1.27	1.28	1.29
28.00	1.23	1.24	1.24	1.24	1.25	1.25	1.26	1.26	1.28
29.00	1.22	1.23	1.23	1.23	1.24	1.24	1.24	1.25	1.27
30.00	1.22	1.22	1.22	1.22	1.23	1.23	1.23	1.24	1.26
32.00	1.20	1.20	1.20	1.21	1.21	1.21	1.22	1.22	1.24
34.00	1.19	1.19	1.19	1.19	1.20	1.20	1.20	1.21	1.22
36.00	1.17	1.18	1.18	1.18	1.18	1.19	1.19	1.19	1.21
38.00	1.16	1.16	1.17	1.17	1.17	1.17	1.18	1.18	1.19
40.00	1.15	1.16	1.16	1.16	1.16	1.16	1.17	1.17	1.18
42.00	1.14	1.15	1.15	1.15	1.15	1.15	1.16	1.16	1.17
44.00	1.14	1.14	1.14	1.14	1.14	1.15	1.15	1.15	1.16
46.00	1.13	1.13	1.13	1.14	1.14	1.14	1.14	1.15	1.15
48.00	1.12	1.13	1.13	1.13	1.13	1.13	1.13	1.14	1.15
50.00	1.12	1.12	1.12	1.12	1.13	1.13	1.13	1.13	1.14
52.00	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13
54.00	1.11	1.11	1.11	1.11	1.11	1.12	1.12	1.12	1.13
56.00	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.12	1.12
58.00	1.10	1.10	1.10	1.10	1.11	1.11	1.11	1.11	1.12
60.00	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11
62.00	1.09	1.09	1.10	1.10	1.10	1.10	1.10	1.10	1.11
64.00	1.09	1.09	1.09	1.09	1.10	1.10	1.10	1.10	1.11
66.00	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.10	1.10
68.00	1.08	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.10
70.00	1.08	1.08	1.08	1.09	1.09	1.09	1.09	1.09	1.10
72.00	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09

Table 8

Values of h/d for 5.5-in. Concrete Cover

h (INCHES)	#5	#6	#7	#8	#9	#10	#11	#14S	#18S
18.00	1.48	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.58
19.00	1.44	1.45	1.45	1.46	1.47	1.48	1.49	1.50	1.54
20.00	1.41	1.42	1.42	1.43	1.44	1.44	1.45	1.46	1.50
21.00	1.38	1.39	1.39	1.40	1.41	1.41	1.42	1.43	1.46
22.00	1.36	1.36	1.37	1.38	1.38	1.39	1.39	1.41	1.43
23.00	1.34	1.34	1.35	1.35	1.36	1.36	1.37	1.38	1.40
24.00	1.32	1.32	1.33	1.33	1.34	1.34	1.35	1.36	1.38
25.00	1.30	1.31	1.31	1.32	1.32	1.33	1.33	1.34	1.36
26.00	1.29	1.29	1.30	1.30	1.30	1.31	1.31	1.32	1.34
27.00	1.27	1.28	1.28	1.29	1.29	1.29	1.30	1.31	1.33
28.00	1.26	1.27	1.27	1.27	1.28	1.28	1.28	1.29	1.31
29.00	1.25	1.25	1.26	1.26	1.26	1.27	1.27	1.28	1.30
30.00	1.24	1.24	1.25	1.25	1.25	1.26	1.26	1.27	1.28
32.00	1.22	1.22	1.23	1.23	1.23	1.24	1.24	1.25	1.26
34.00	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.23	1.24
36.00	1.19	1.20	1.20	1.20	1.20	1.21	1.21	1.21	1.23
38.00	1.18	1.18	1.19	1.19	1.19	1.19	1.20	1.20	1.21
40.00	1.17	1.17	1.17	1.18	1.18	1.18	1.18	1.19	1.20
42.00	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.18	1.19
44.00	1.15	1.15	1.16	1.16	1.16	1.16	1.16	1.17	1.18
46.00	1.14	1.15	1.15	1.15	1.15	1.15	1.16	1.16	1.17
48.00	1.14	1.14	1.14	1.14	1.14	1.15	1.15	1.15	1.16
50.00	1.13	1.13	1.13	1.14	1.14	1.14	1.14	1.15	1.15
52.00	1.13	1.13	1.13	1.13	1.13	1.13	1.14	1.14	1.15
54.00	1.12	1.12	1.12	1.13	1.13	1.13	1.13	1.13	1.14
56.00	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13
58.00	1.11	1.11	1.11	1.12	1.12	1.12	1.12	1.12	1.13
60.00	1.11	1.11	1.11	1.11	1.11	1.11	1.12	1.12	1.12
62.00	1.10	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.12
64.00	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11	1.12
66.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11
68.00	1.09	1.09	1.10	1.10	1.10	1.10	1.10	1.10	1.11
70.00	1.09	1.09	1.09	1.09	1.09	1.10	1.10	1.10	1.10
72.00	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.10	1.10

Table 9

Values of h/d for 6.0-in. Concrete Cover

h (INCHES)	BAR SIZE #5	#6	#7	#8	#9	#10	#11	#14	#18
18.00	1.54	1.55	1.56	1.57	1.57	1.58	1.59	1.61	1.66
19.00	1.50	1.50	1.51	1.52	1.53	1.54	1.55	1.56	1.60
20.00	1.46	1.47	1.47	1.48	1.49	1.50	1.50	1.52	1.55
21.00	1.43	1.44	1.44	1.45	1.45	1.46	1.47	1.48	1.51
22.00	1.40	1.41	1.41	1.42	1.43	1.43	1.44	1.45	1.48
23.00	1.38	1.38	1.39	1.39	1.40	1.41	1.41	1.42	1.45
24.00	1.36	1.36	1.37	1.37	1.38	1.38	1.39	1.40	1.42
25.00	1.34	1.34	1.35	1.35	1.36	1.36	1.37	1.38	1.40
26.00	1.32	1.32	1.33	1.33	1.34	1.34	1.35	1.36	1.38
27.00	1.31	1.31	1.31	1.32	1.32	1.33	1.33	1.34	1.36
28.00	1.29	1.29	1.30	1.30	1.31	1.31	1.31	1.32	1.34
29.00	1.28	1.28	1.29	1.29	1.29	1.30	1.30	1.31	1.33
30.00	1.27	1.27	1.27	1.28	1.28	1.28	1.29	1.30	1.31
32.00	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.27	1.29
34.00	1.23	1.23	1.23	1.24	1.24	1.24	1.25	1.25	1.27
36.00	1.21	1.22	1.22	1.22	1.22	1.23	1.23	1.23	1.25
38.00	1.20	1.20	1.20	1.21	1.21	1.21	1.21	1.22	1.23
40.00	1.19	1.19	1.19	1.19	1.20	1.20	1.20	1.21	1.22
42.00	1.18	1.18	1.18	1.18	1.19	1.19	1.19	1.19	1.20
44.00	1.17	1.17	1.17	1.17	1.18	1.18	1.18	1.18	1.19
46.00	1.16	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.18
48.00	1.15	1.15	1.15	1.16	1.16	1.16	1.16	1.17	1.17
50.00	1.14	1.15	1.15	1.15	1.15	1.15	1.15	1.16	1.17
52.00	1.14	1.14	1.14	1.14	1.14	1.15	1.15	1.15	1.16
54.00	1.13	1.13	1.14	1.14	1.14	1.14	1.14	1.15	1.15
56.00	1.13	1.13	1.13	1.13	1.13	1.13	1.14	1.14	1.15
58.00	1.12	1.12	1.12	1.13	1.13	1.13	1.13	1.13	1.14
60.00	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.13
62.00	1.11	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.13
64.00	1.11	1.11	1.11	1.11	1.11	1.12	1.12	1.12	1.13
66.00	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.12	1.12
68.00	1.10	1.10	1.10	1.11	1.11	1.11	1.11	1.11	1.12
70.00	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11
72.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11

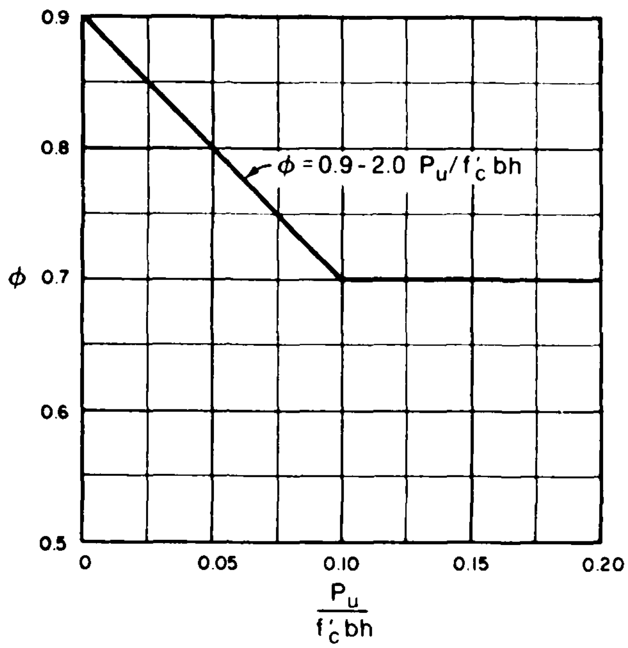
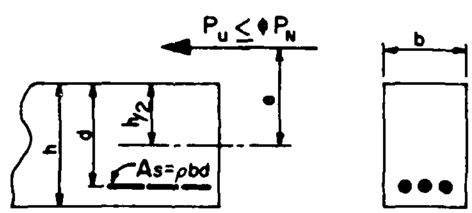


Figure 1. Strength reduction factor, ϕ



LIMITATION

LIMITS FOR POSITIVE AND NEGATIVE VALUES OF e/d ARE GIVEN ON THE GRAPHS. WHEN e/d VALUES ARE OUTSIDE OF THESE LIMITS, DOUBLE REINFORCED MEMBERS SHOULD BE USED.

Figure 2. Notation and limitation, single reinforced members

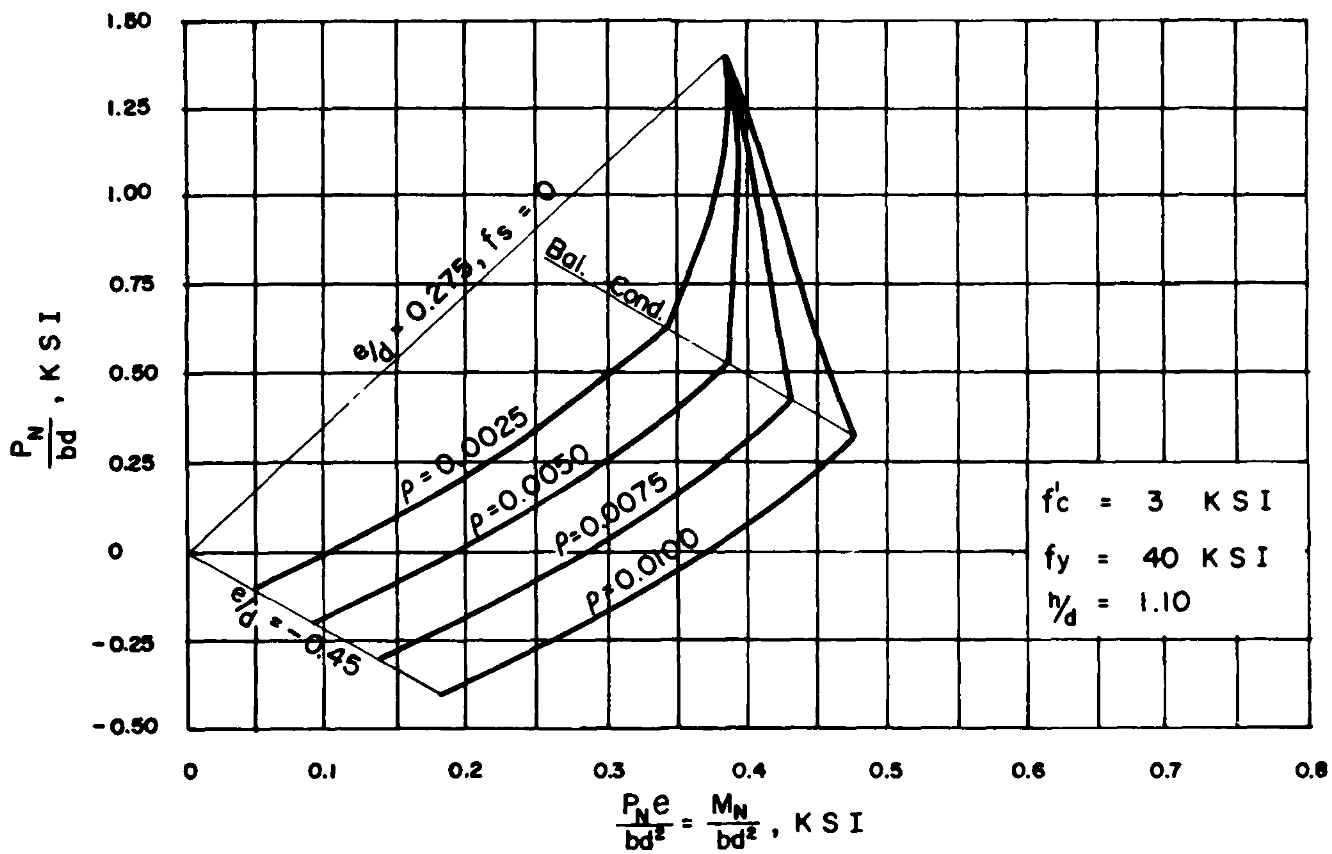


Figure 3. Load-moment strength interaction diagram for single reinforced members (f'_c = 3 ksi, f_y = 40 ksi, and h/d = 1.10)

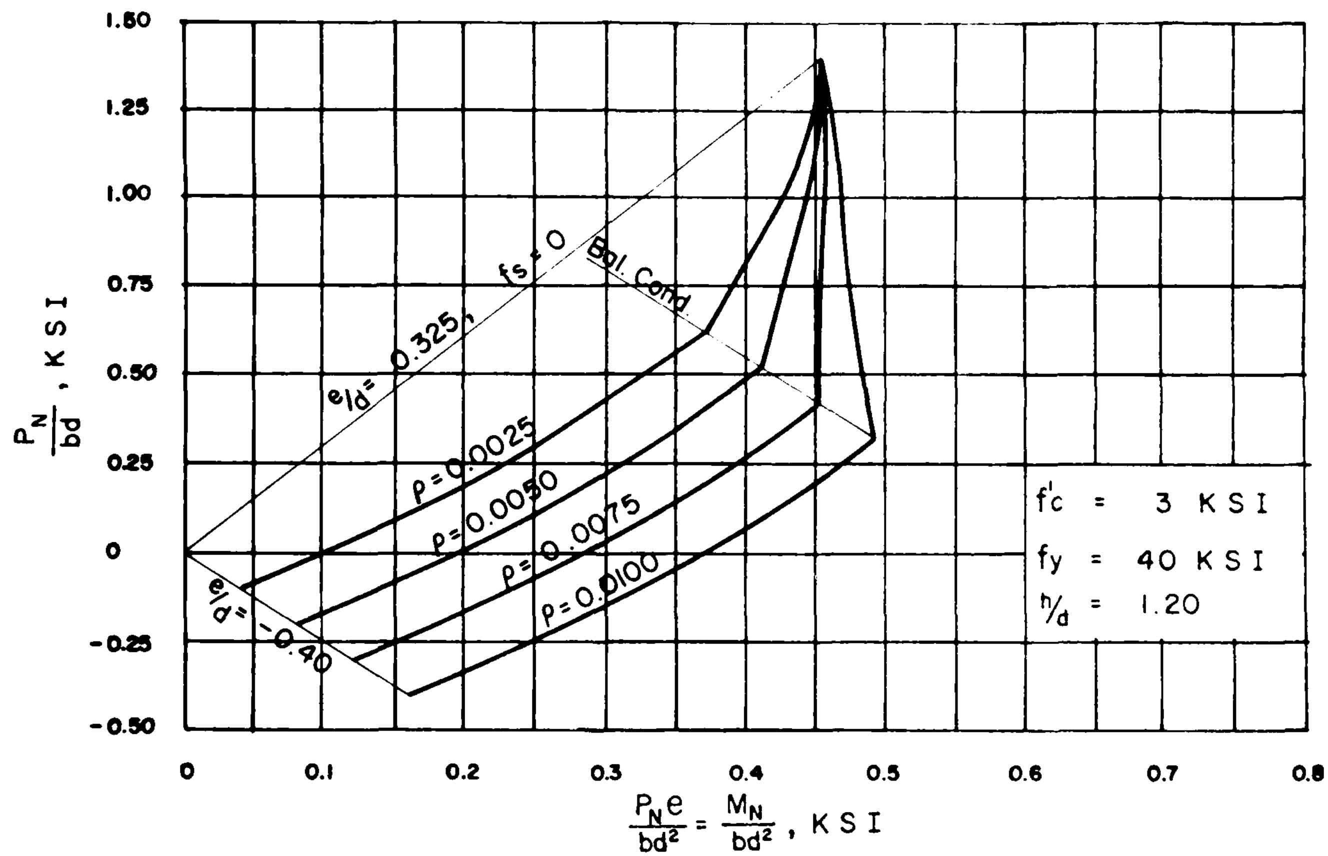


Figure 4. Load-moment strength interaction diagram for single reinforced members (f'_c = 3 ksi, f_y = 40 ksi, and h/d = 1.20)

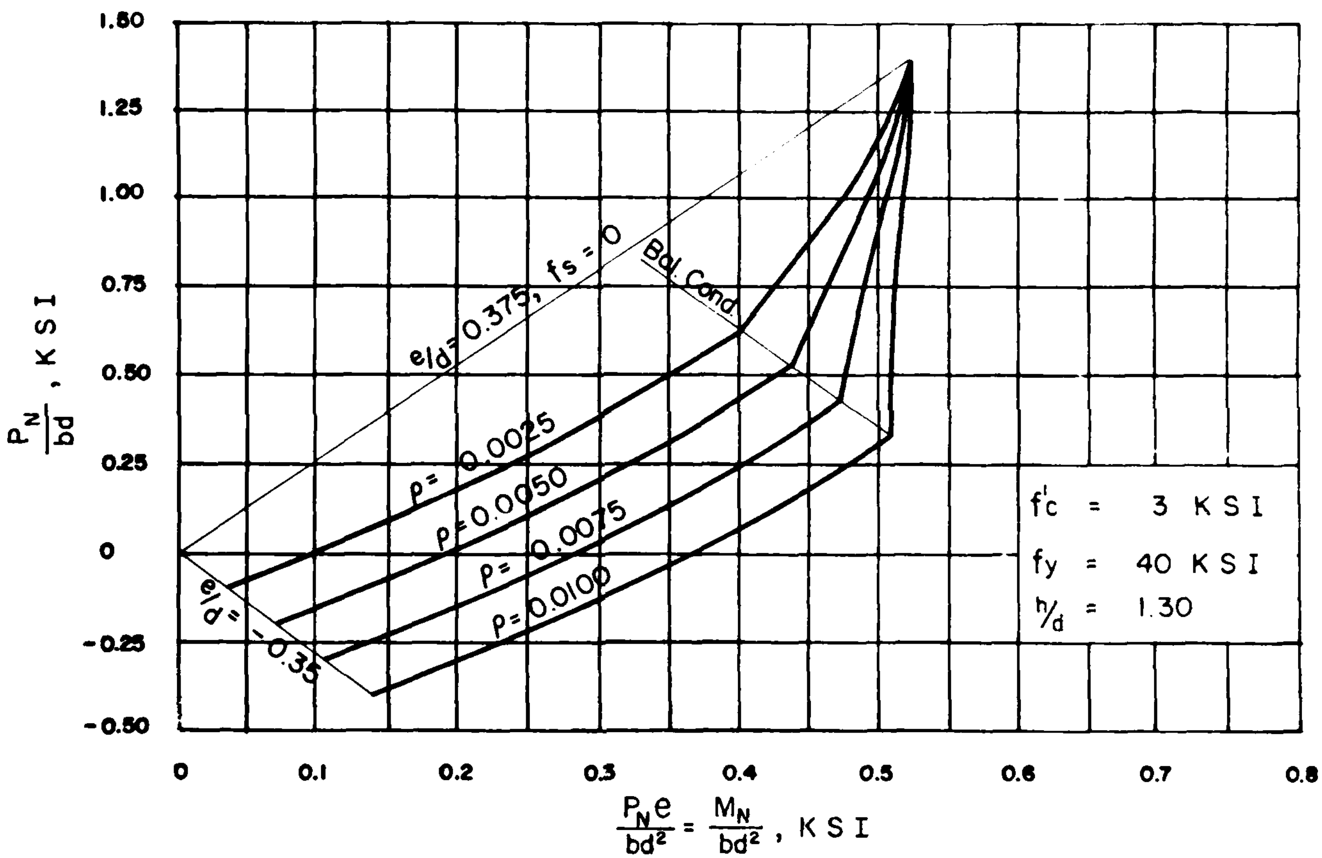


Figure 5. Load-moment strength interaction diagram for single reinforced members (f'_c = 3 ksi, f_y = 40 ksi, and h/d = 1.30)

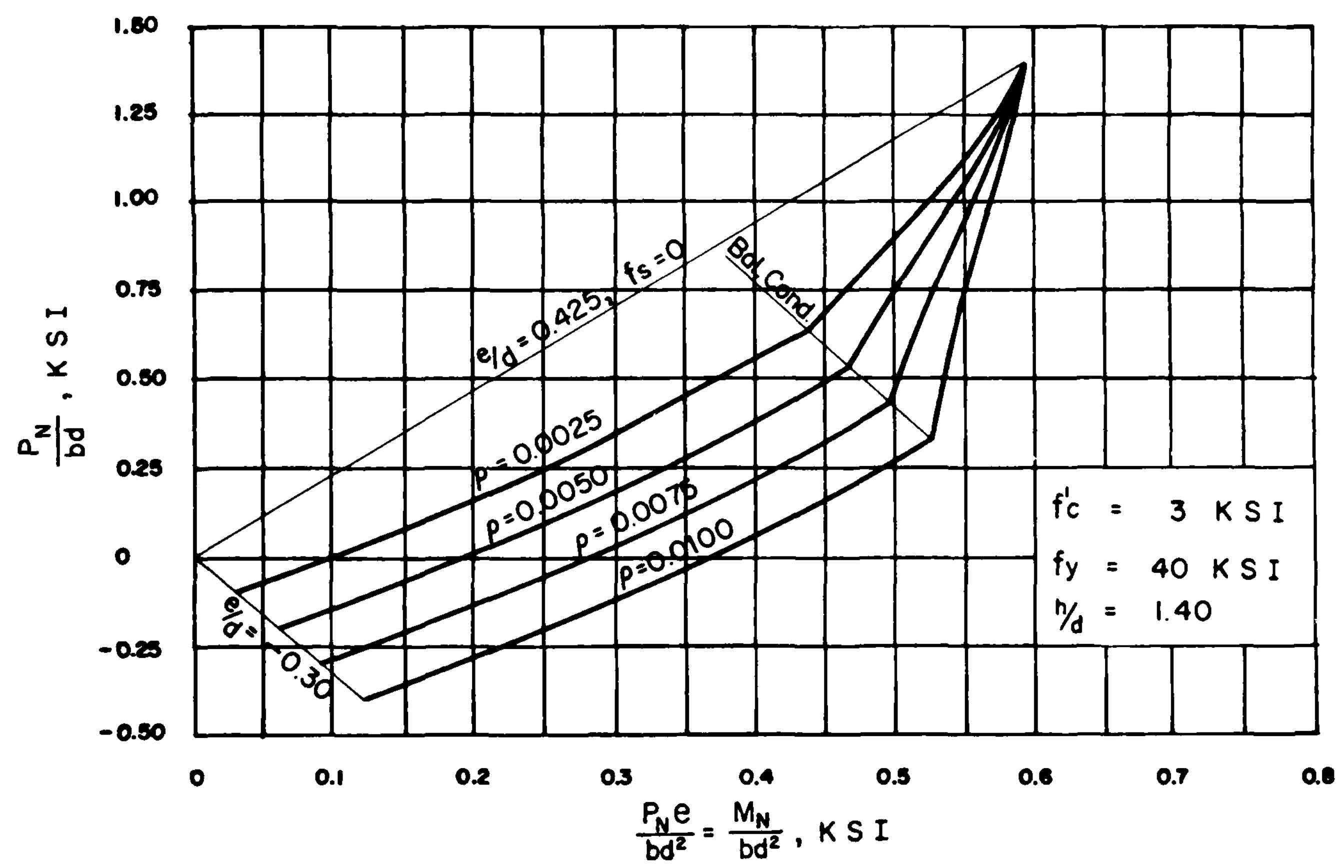


Figure 6. Load-moment strength interaction diagram for single reinforced members (f'_c = 3 ksi, f_y = 40 ksi, and h/d = 1.40)

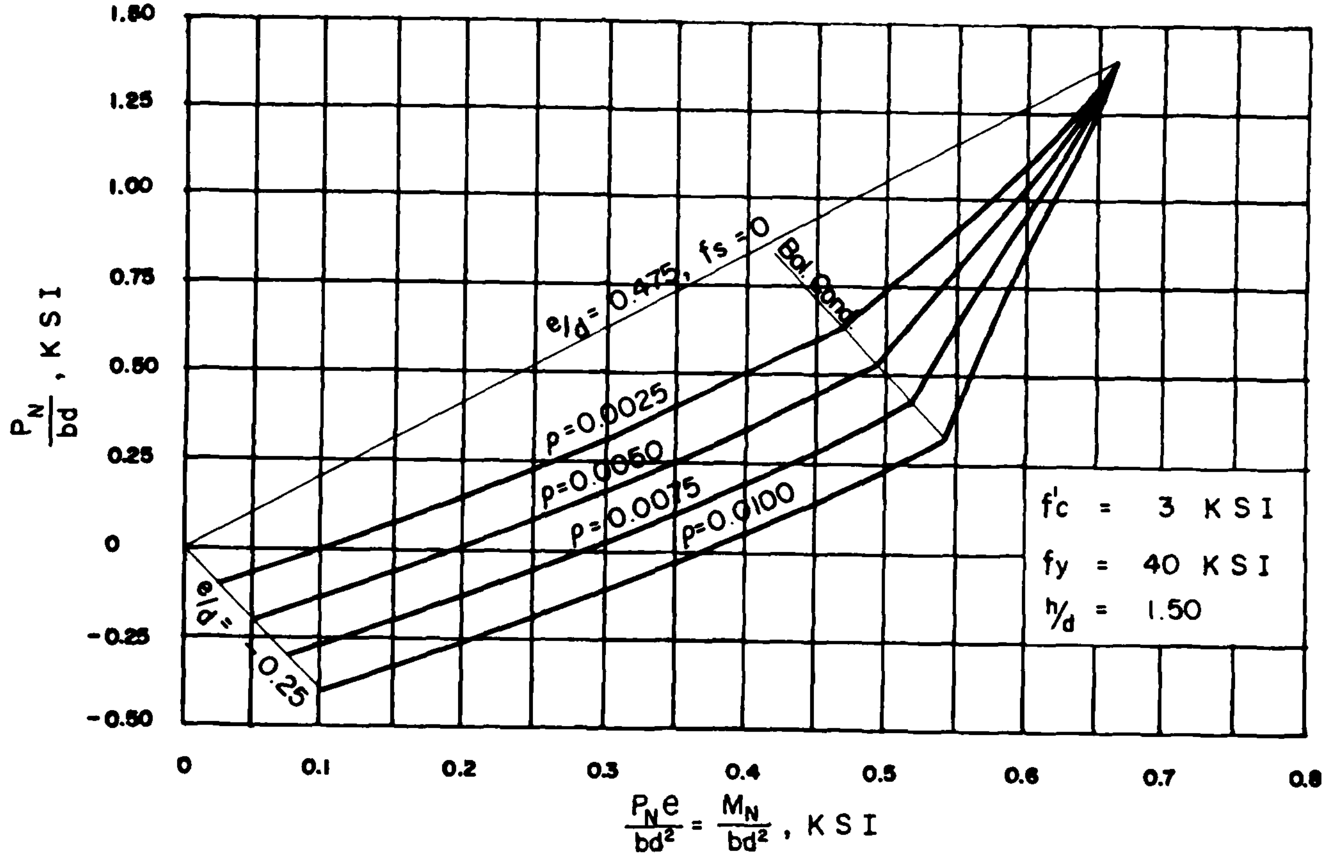


Figure 7. Load-moment strength interaction diagram for singl reinforced members (f'_c = 3 ksi, f_y = 40 ksi, and h/d = 1.50)

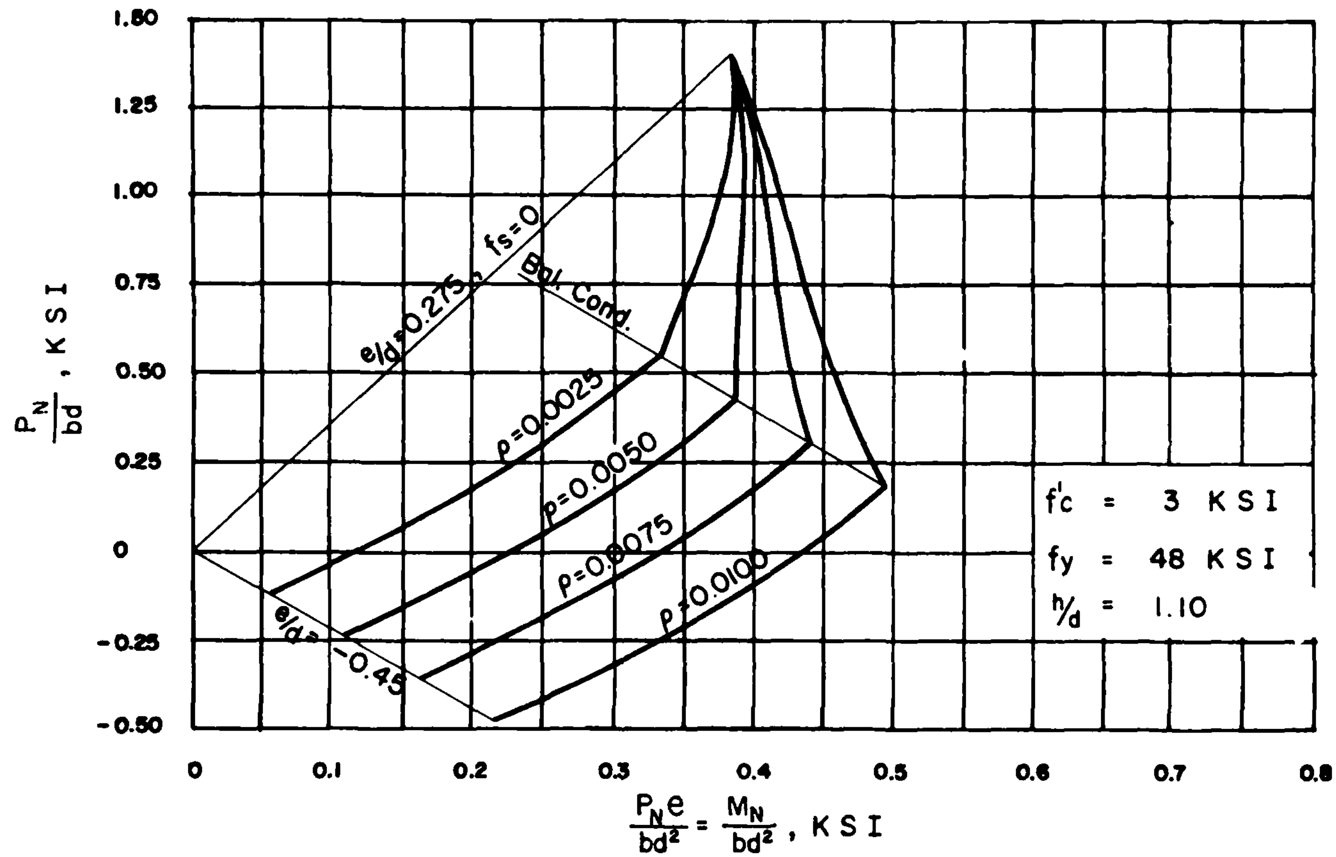


Figure 8. Load-moment strength interaction diagram for single reinforced members (f'_c = 3 ksi, f_y = 48 ksi, and h/d = 1.10)

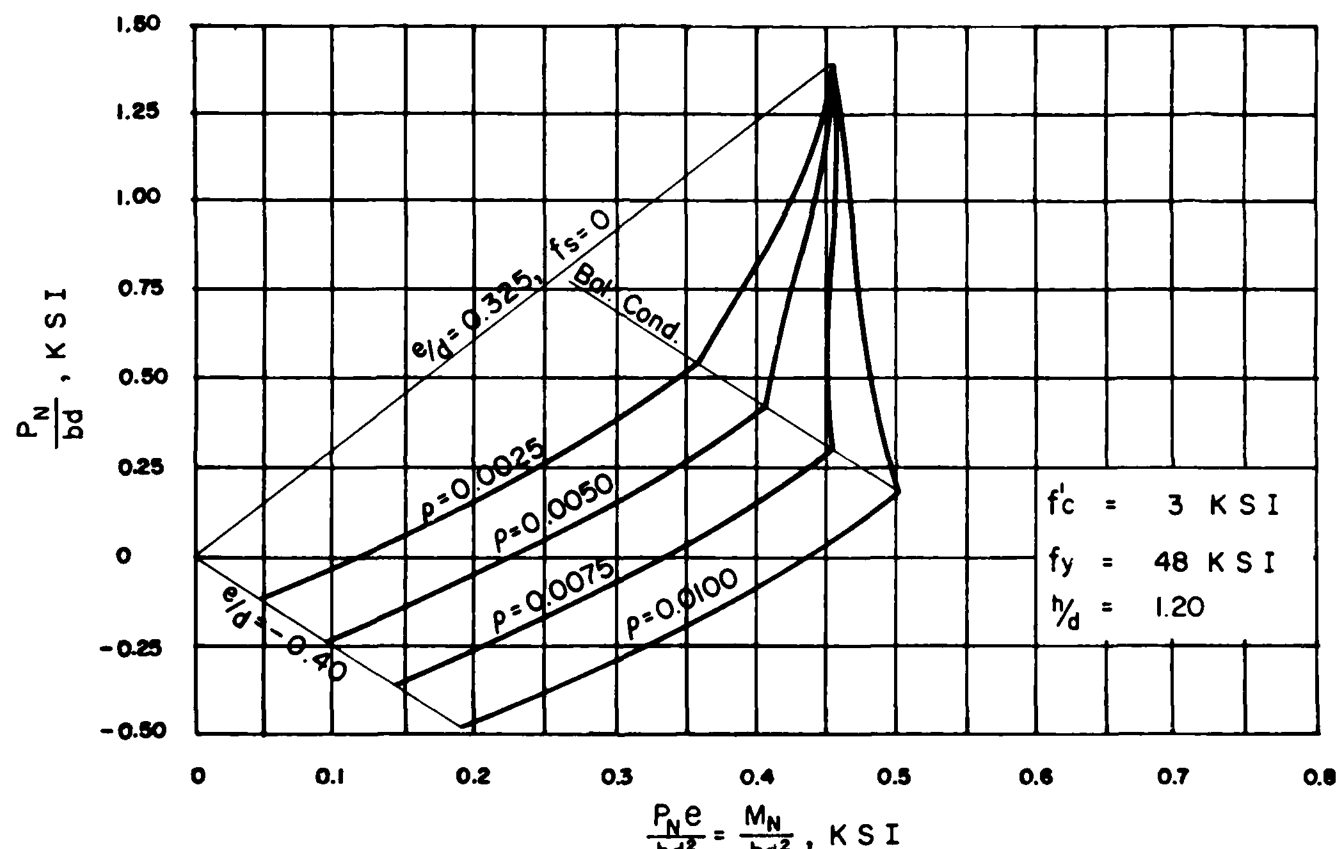


Figure 9. Load-moment strength interaction diagram for single reinforced members (f'_c = 3 ksi, f_y = 48 ksi, and h/d = 1.20)

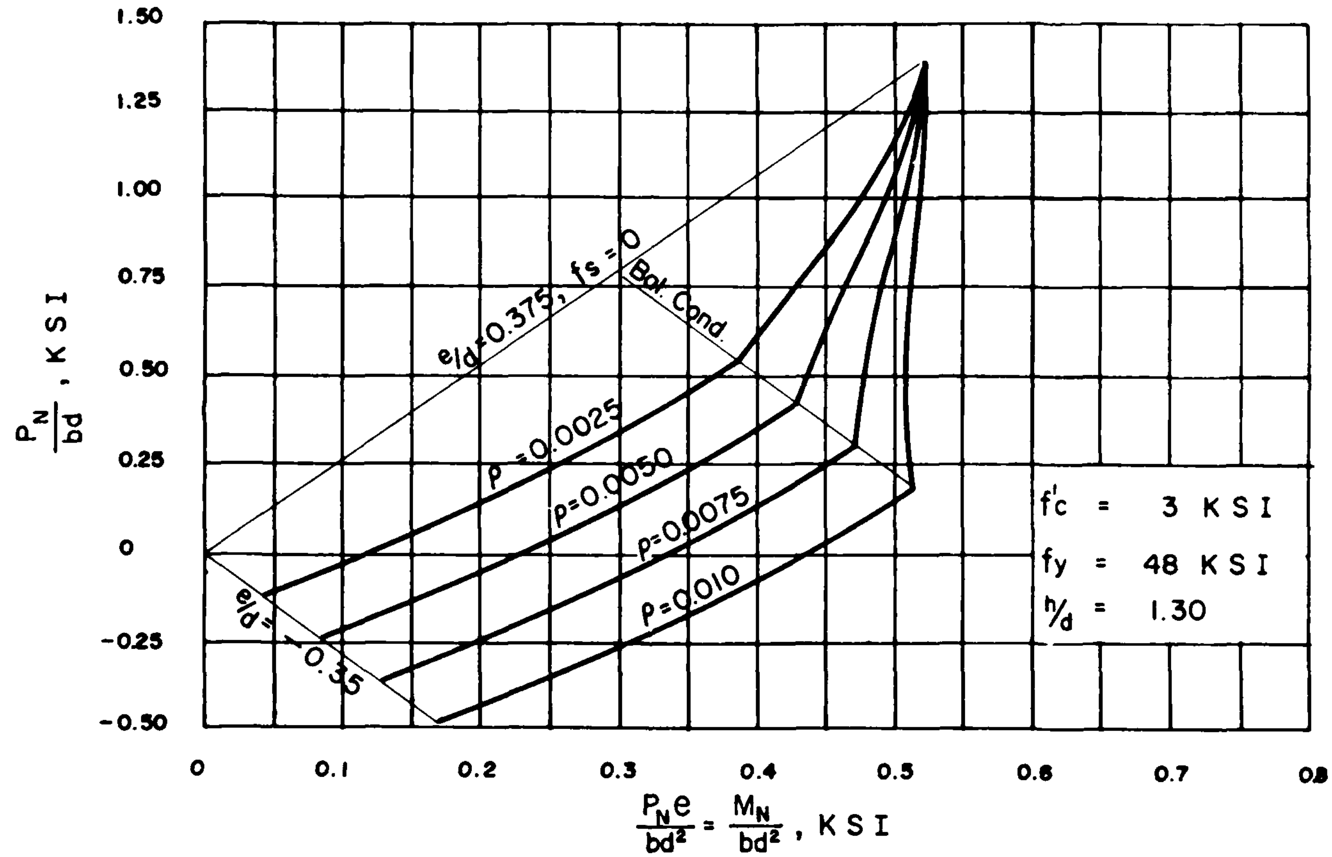


Figure 10. Load-moment strength interaction diagram for single reinforced members (f'_c = 3 ksi, f_y = 48 ksi, and h/d = 1.30)

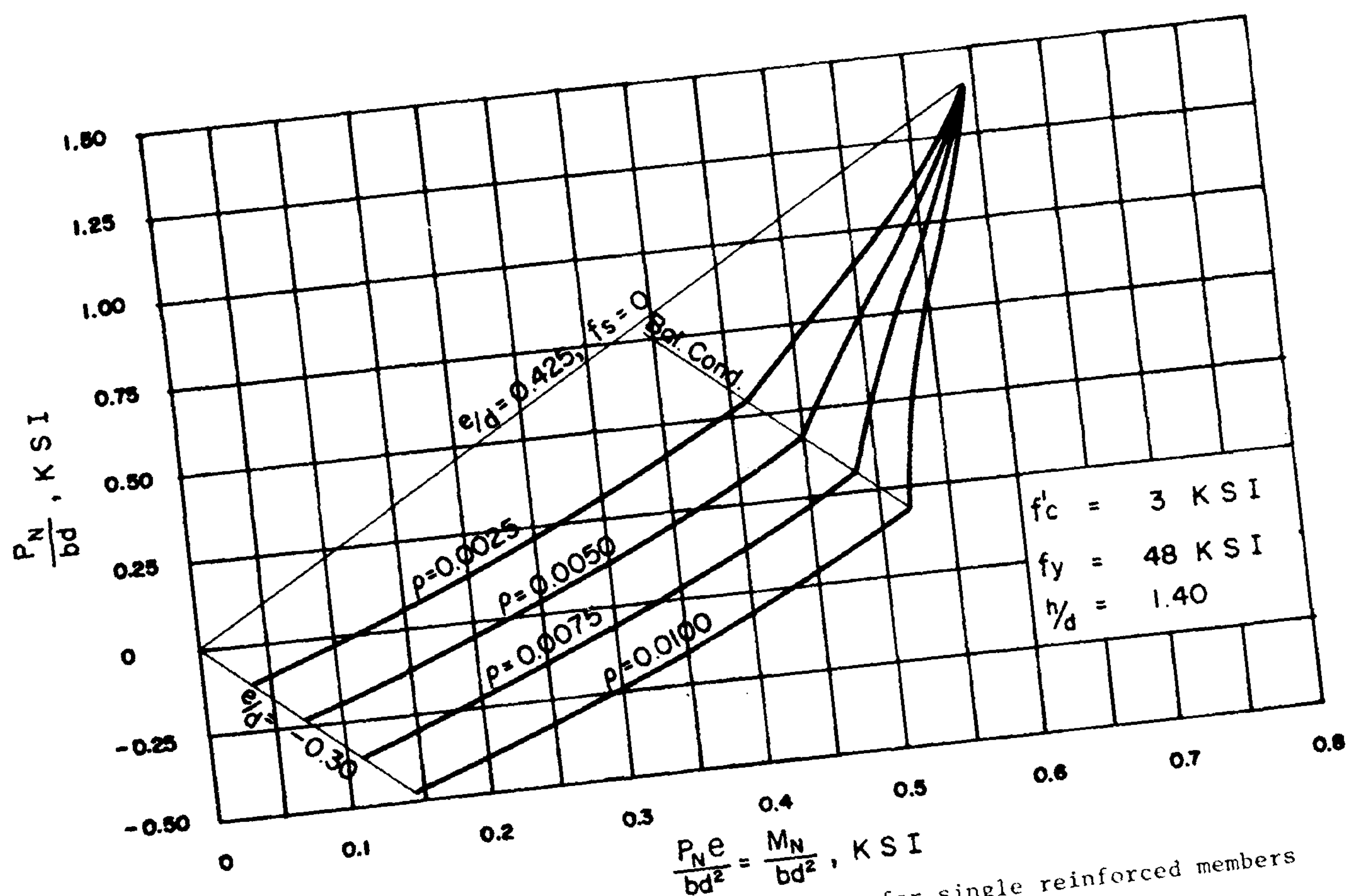


Figure 11. Load-moment strength interaction diagram for single reinforced members (f'_c = 3 ksi, f_y = 48 ksi, and h/d = 1.40)

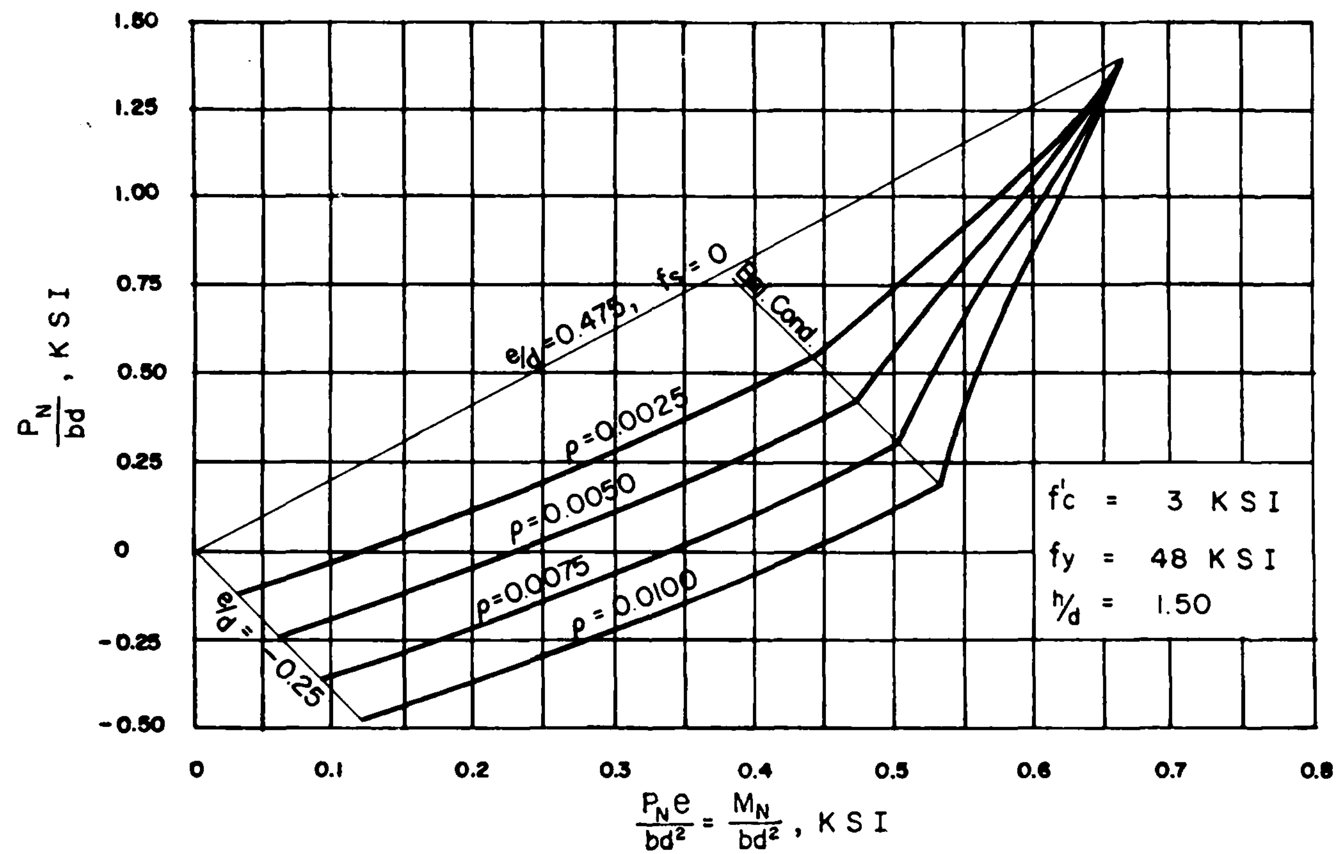


Figure 12. Load-moment strength interaction diagram for single reinforced members (f'_c = 3 ksi, f_y = 48 ksi, and h/d = 1.50)

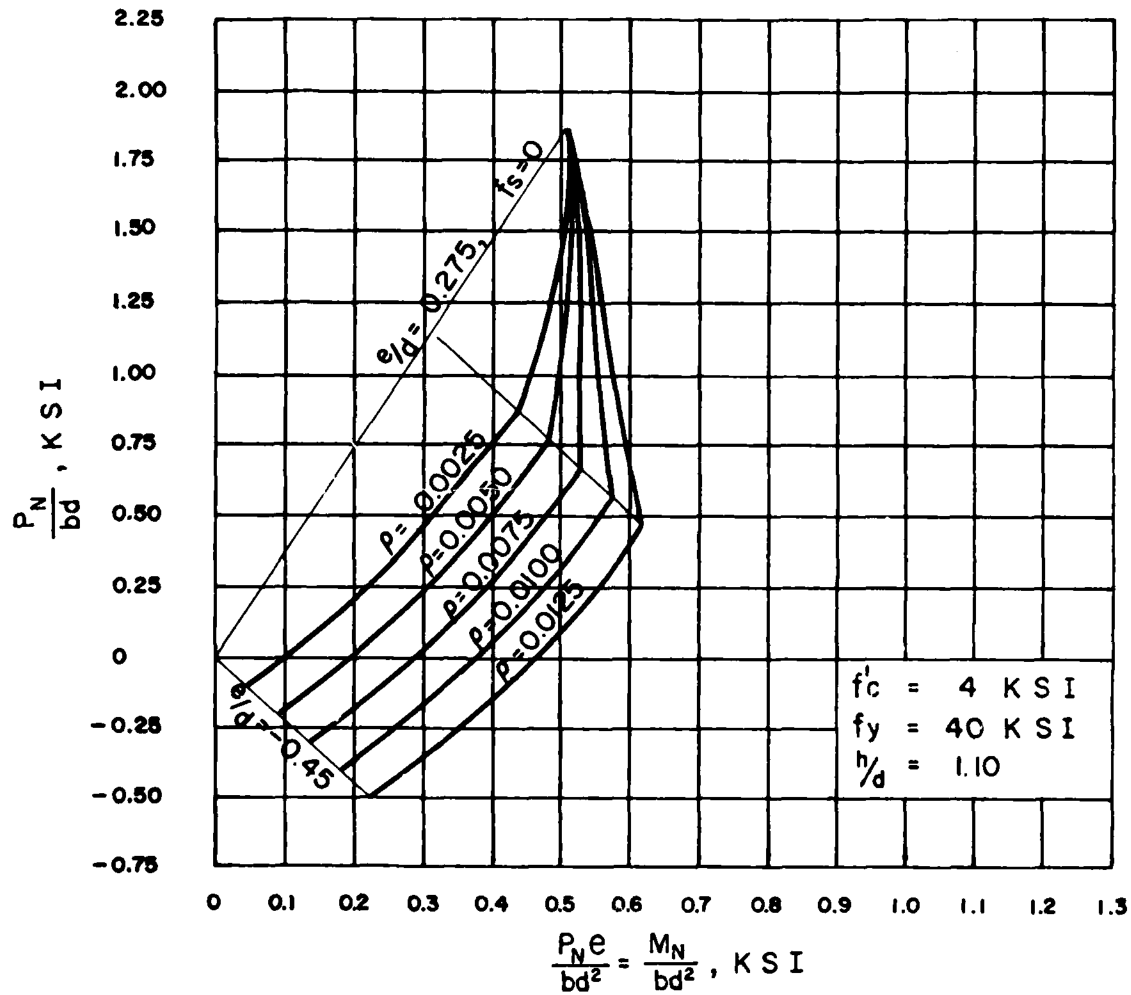


Figure 13. Load-moment strength interaction diagram for single reinforced members (f'_c = 4 ksi, f_y = 40 ksi, and h/d = 1.10)

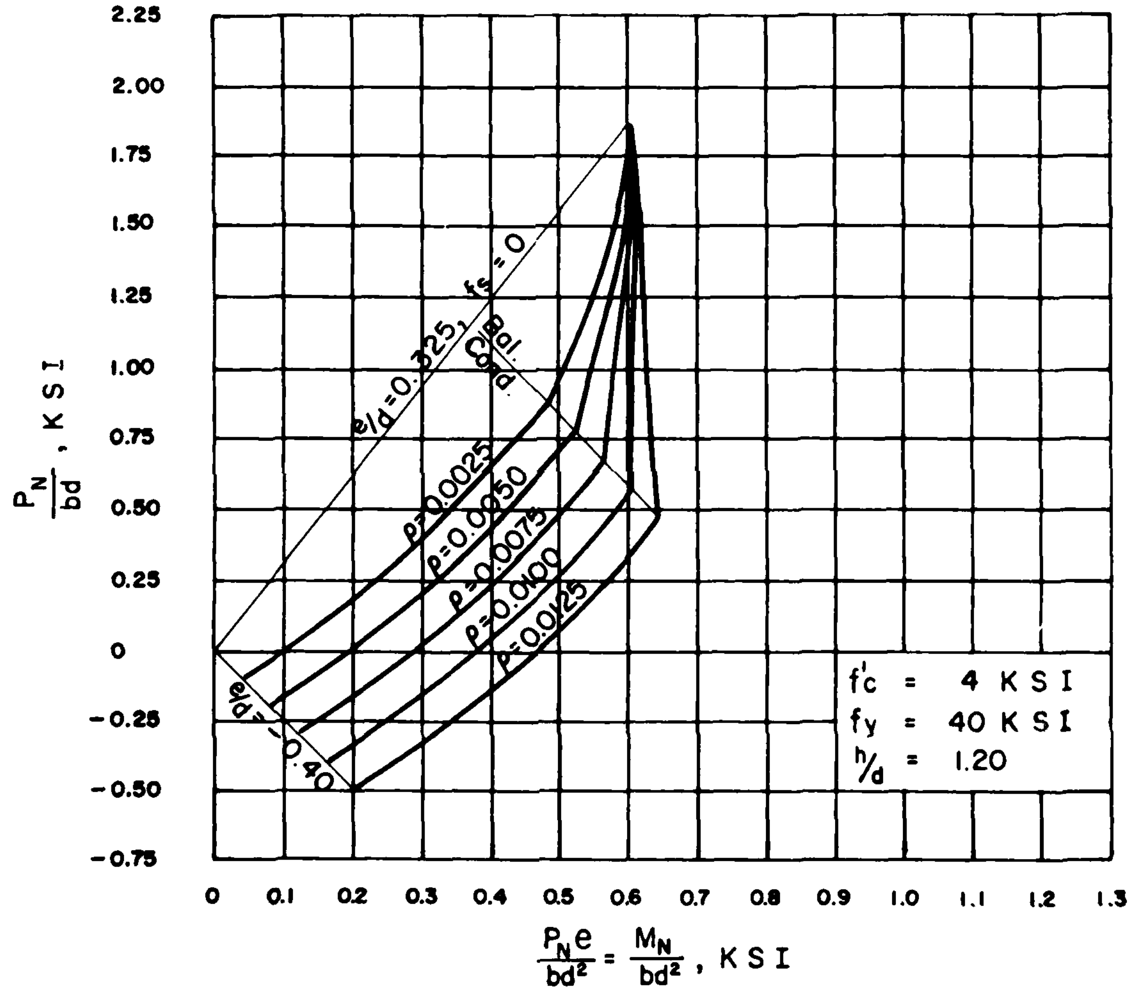


Figure 14. Load-moment strength interaction diagram for single reinforced members (f'_c = 4 ksi, f_y = 40 ksi, and h/d = 1.20)

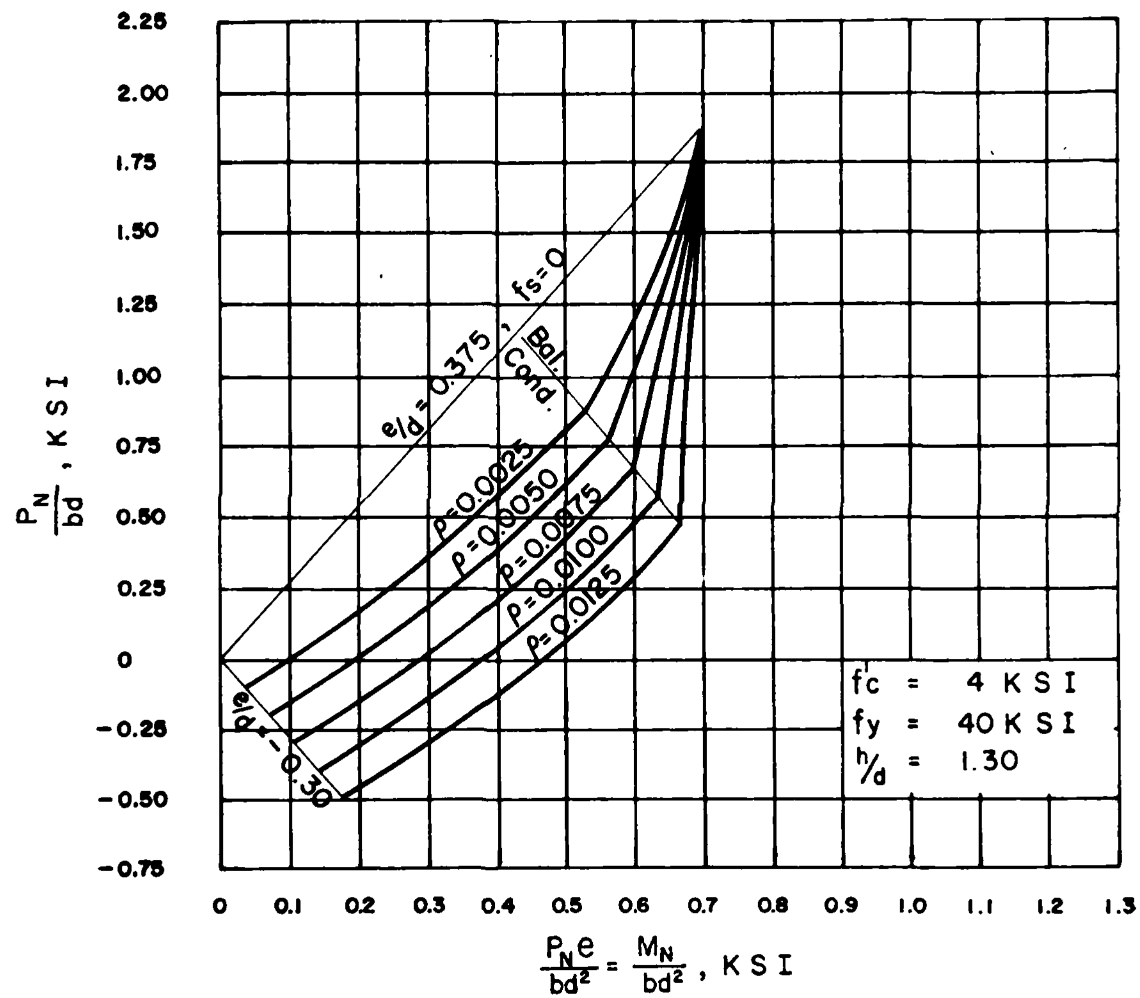


Figure 15. Load-moment strength interaction diagram for single reinforced members (f'_c = 4 ksi, f_y = 40 ksi, and h/d = 1.30)

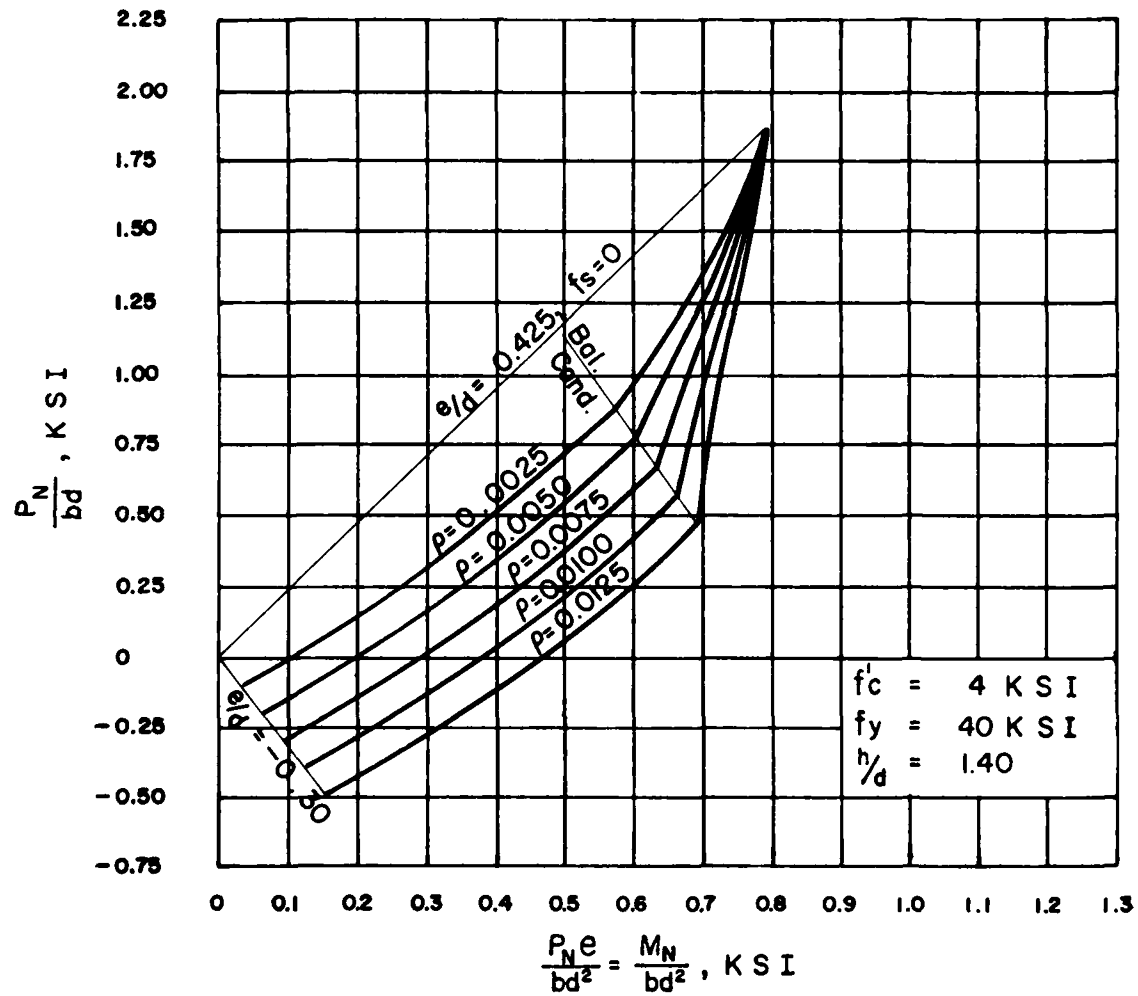


Figure 16. Load-moment strength interaction diagram for single reinforced members (f'_c = 4 ksi, f_y = 40 ksi, and h/d = 1.40)

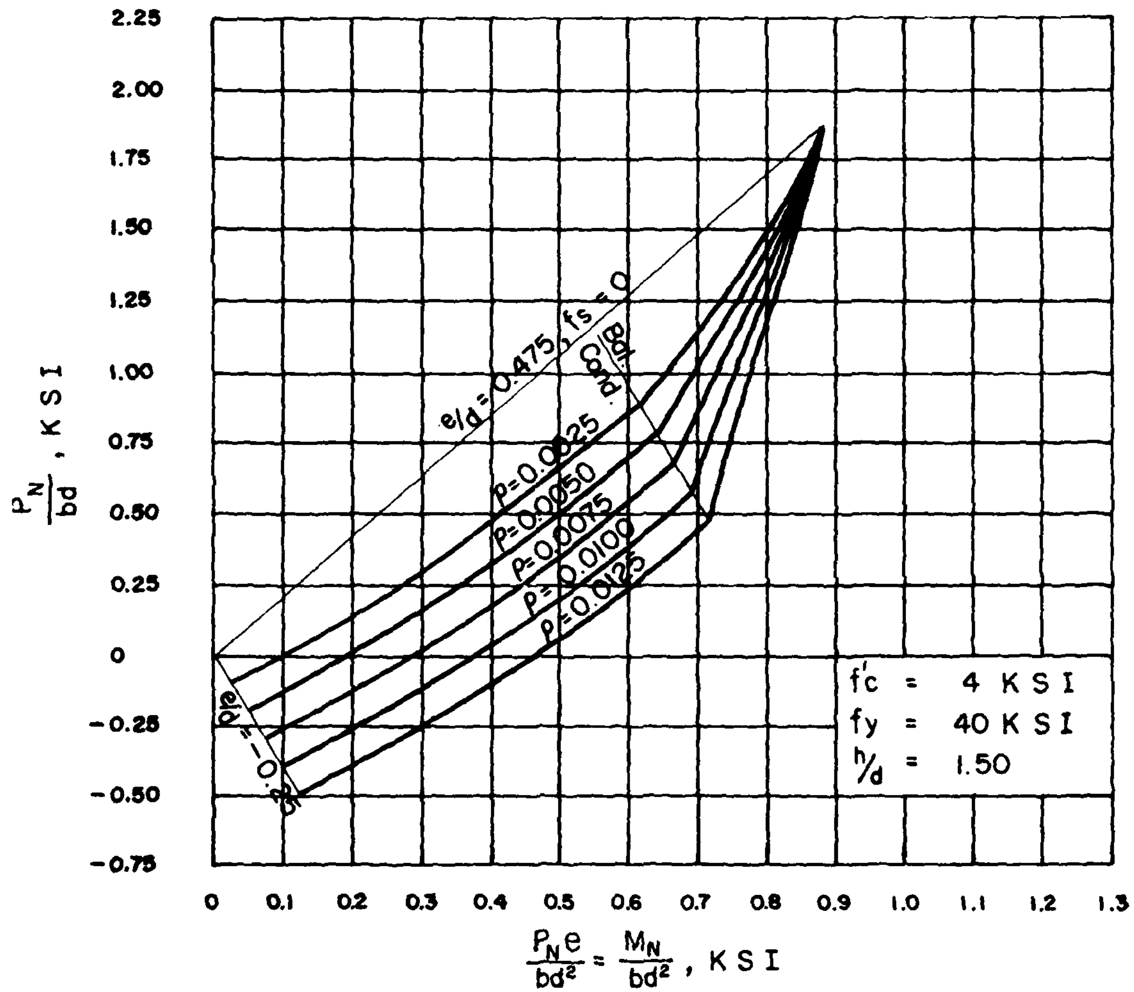


Figure 17. Load-moment strength interaction diagram for single reinforced members (f'_c = 4 ksi, f_y = 40 ksi, and h/d = 1.50)

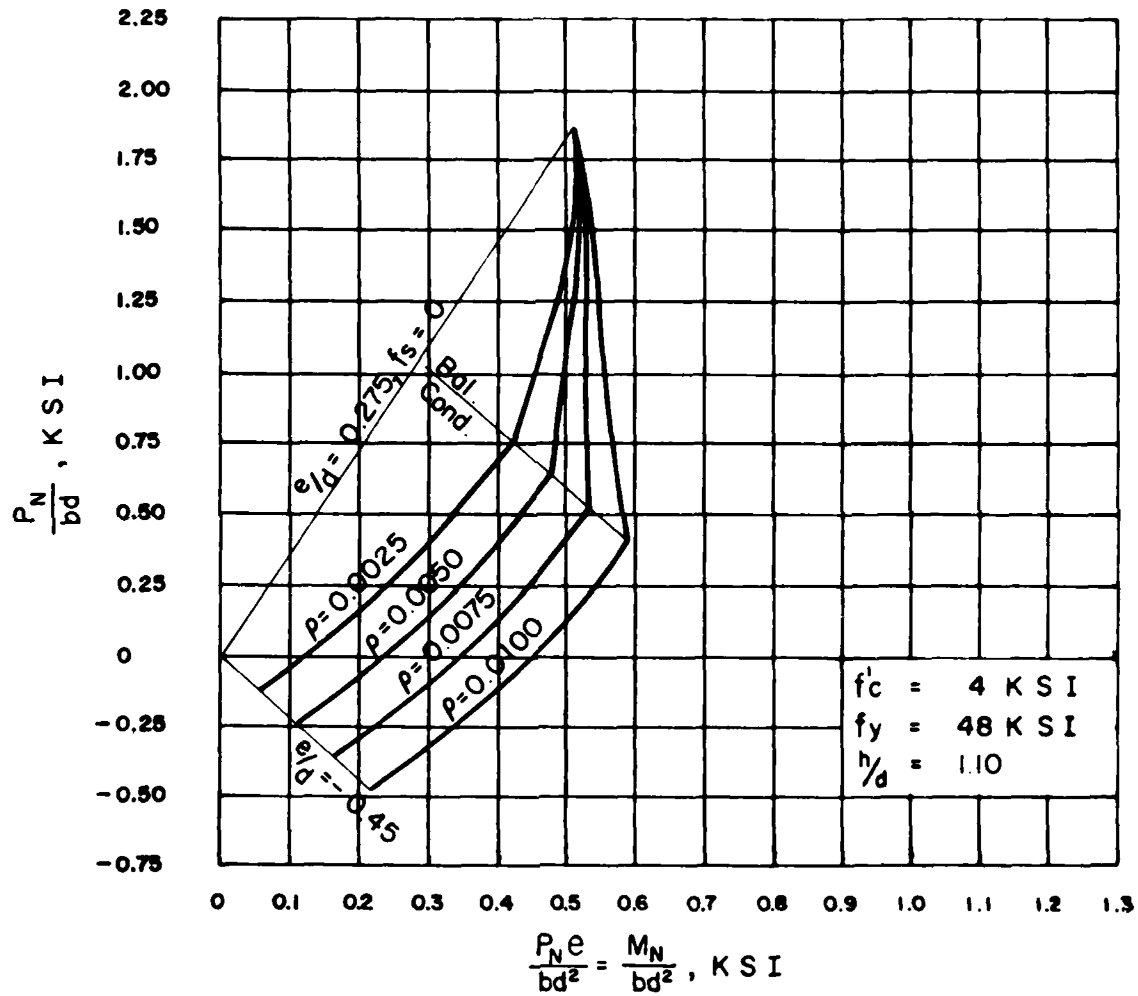


Figure 18. Load-moment strength interaction diagram for single reinforced members (f'_c = 4 ksi, f_y = 48 ksi, and h/d = 1.10)

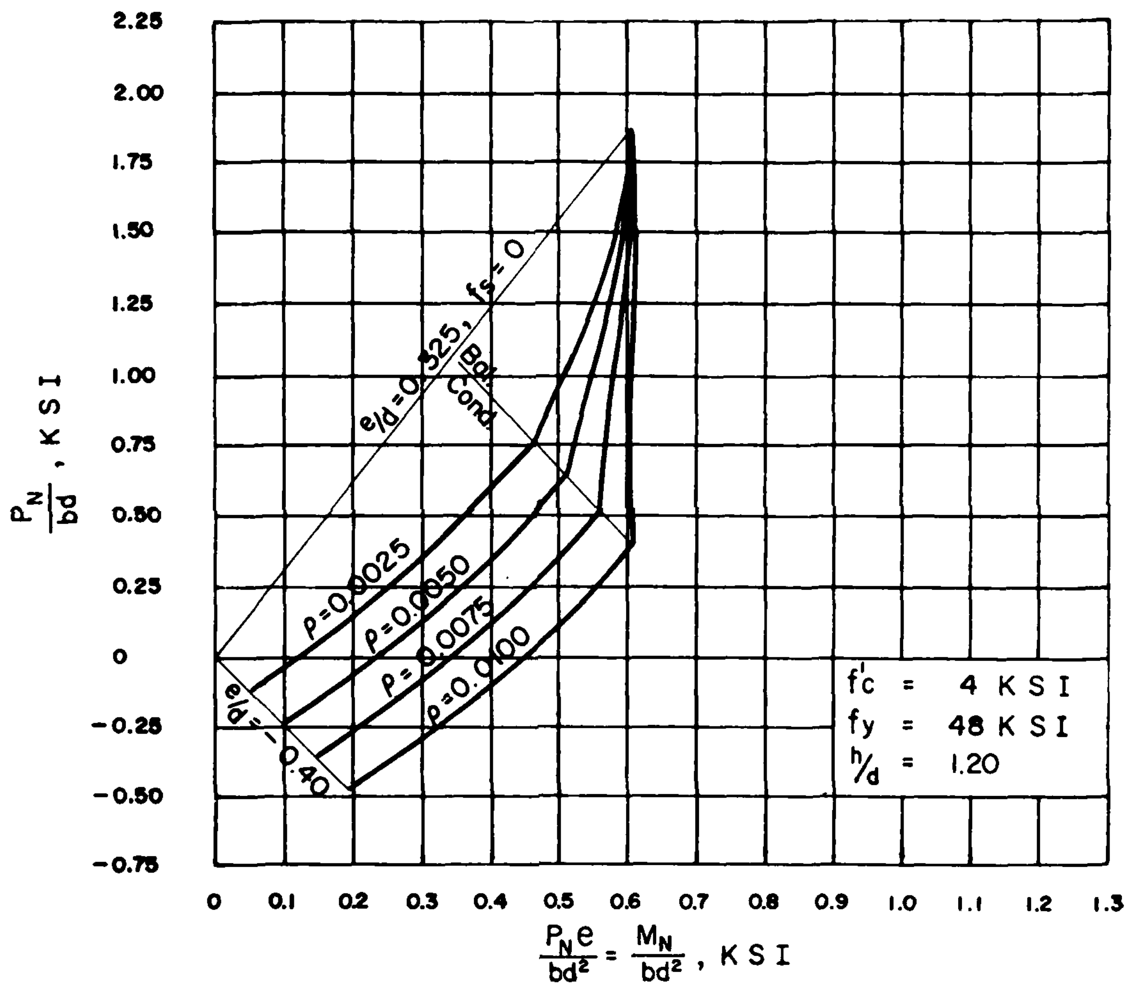


Figure 19. Load-moment strength interaction diagram for single reinforced members (f'_c = 4 ksi, f_y = 48 ksi, and h/d = 1.20)

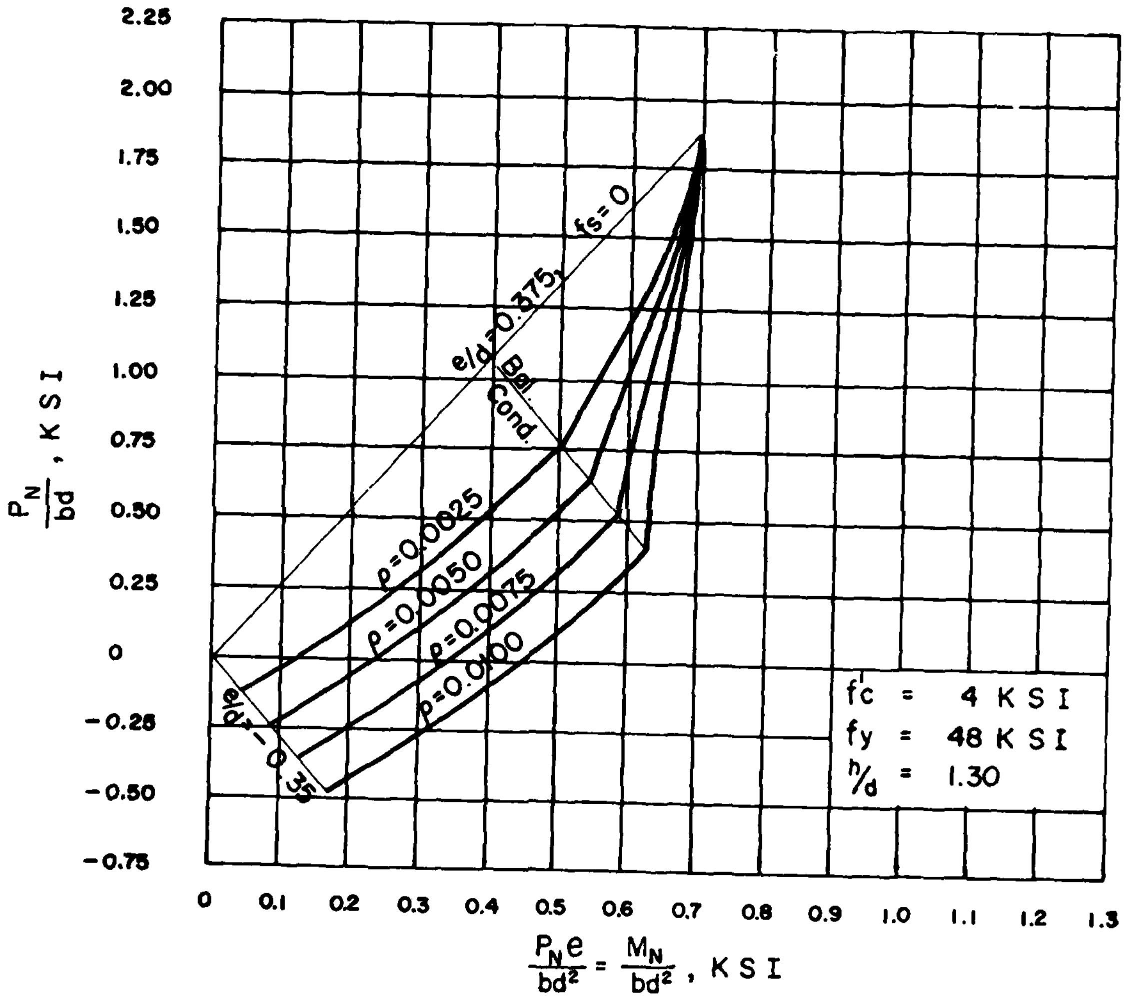


Figure 20. Load-moment strength interaction diagram for single reinforced members (f'_c = 4 ksi, f_y = 48 ksi, and h/d = 1.30)

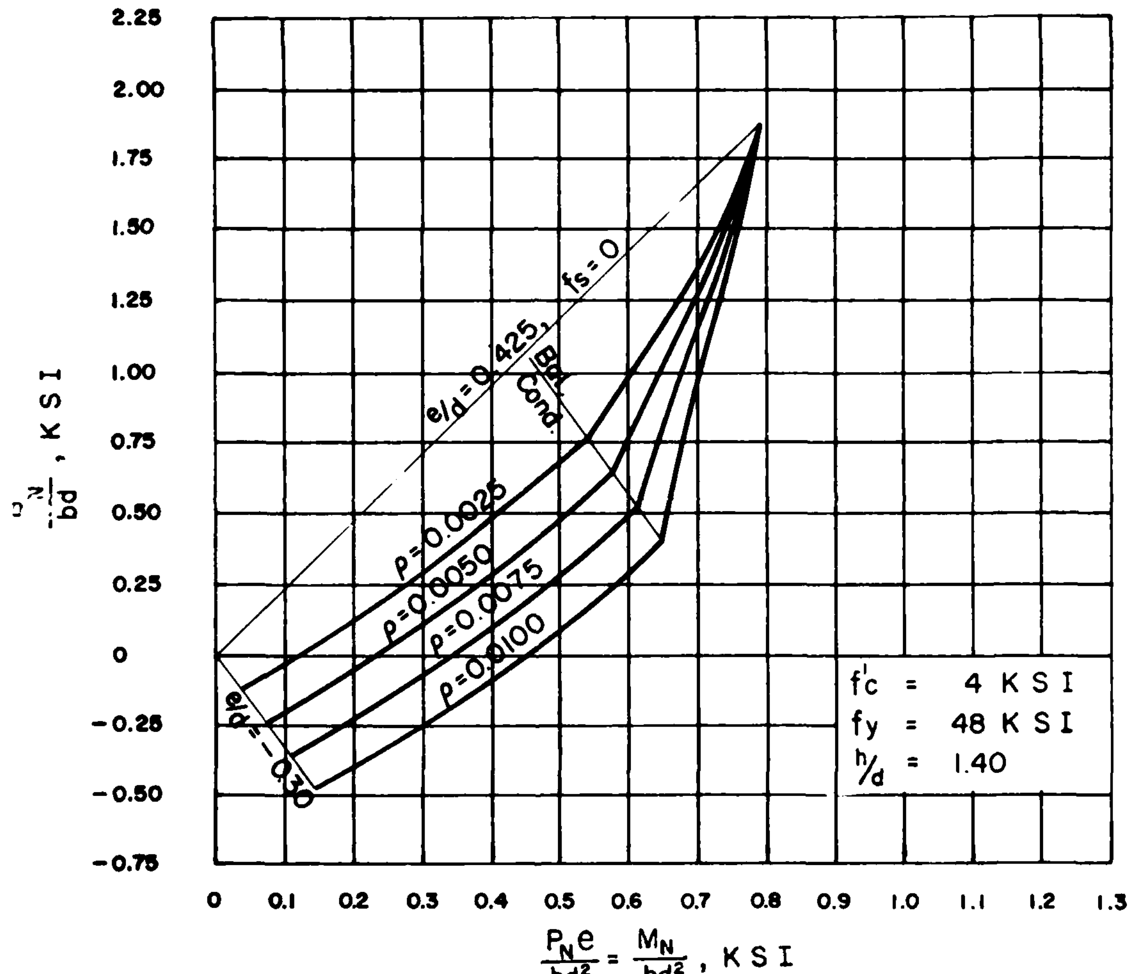


Figure 21. Load-moment strength interaction diagram for single reinforced members (f'_c = 4 ksi, f_y = 48 ksi, and h/d = 1.40)

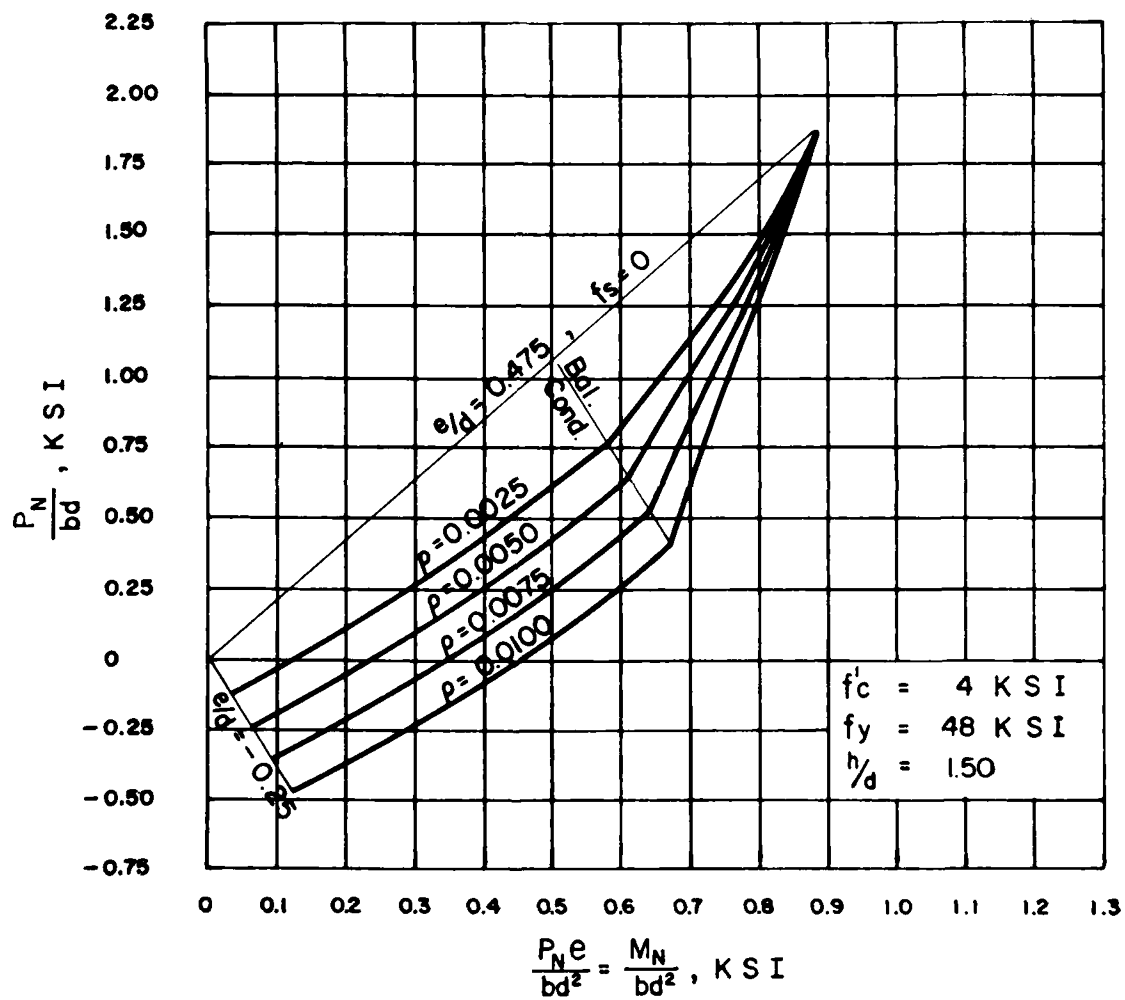


Figure 22. Load-moment strength interaction diagram for single reinforced members (f'_c = 4 ksi, f_y = 48 ksi, and h/d = 1.50)

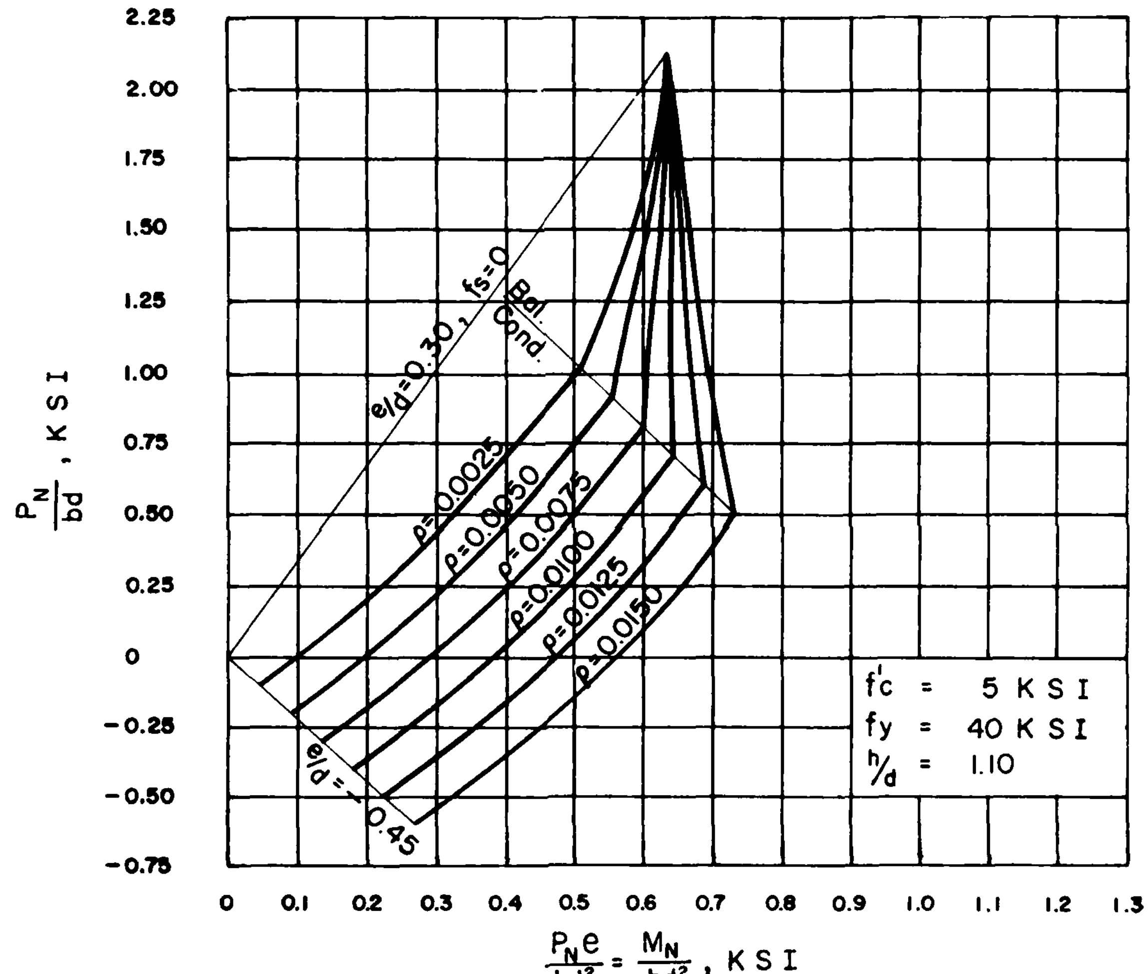


Figure 23. Load-moment strength interaction diagram for single reinforced members (f'_c = 5 ksi, f_y = 40 ksi, and h/d = 1.10)

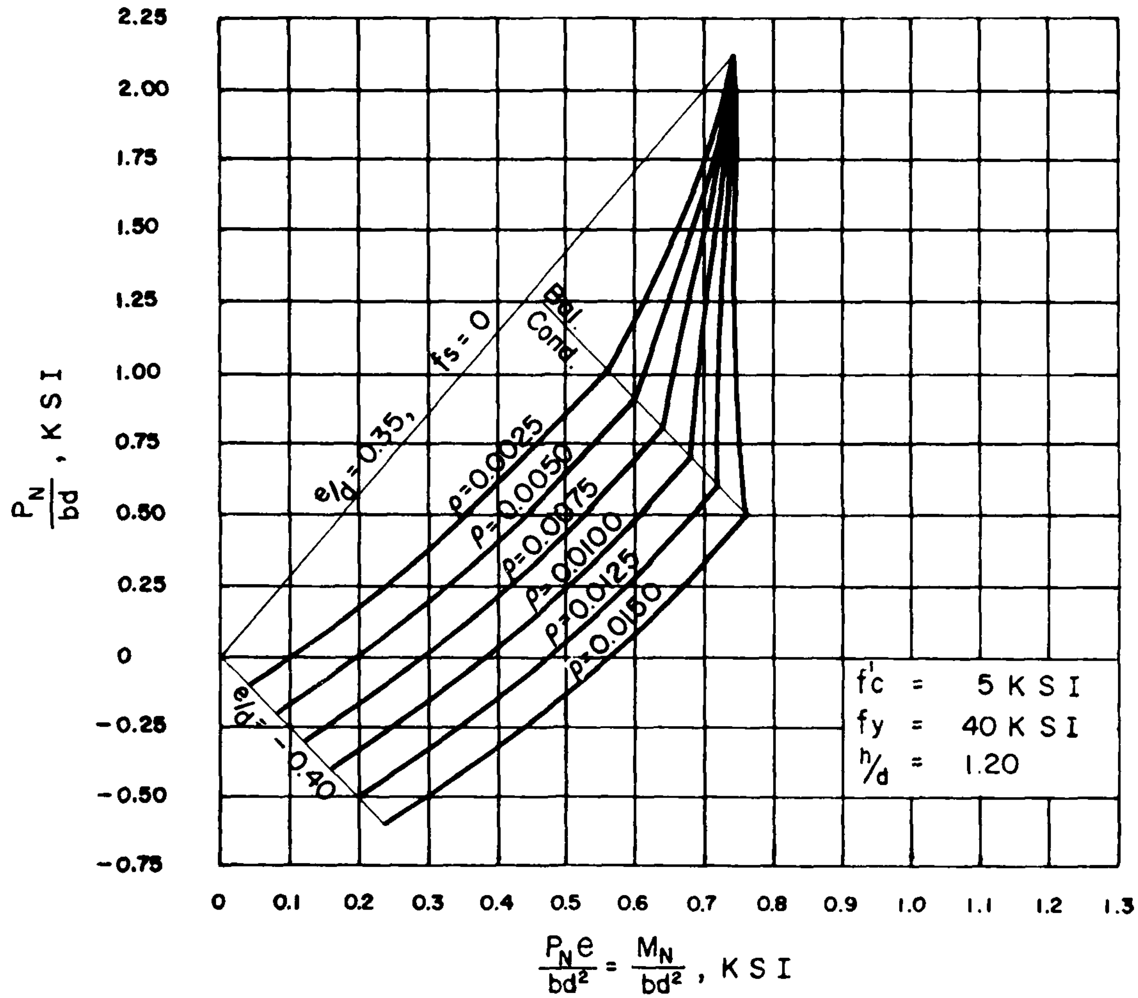


Figure 24. Load-moment strength interaction diagram for single reinforced members (f'_c = 5 ksi, f_y = 40 ksi, and h/d = 1.20)

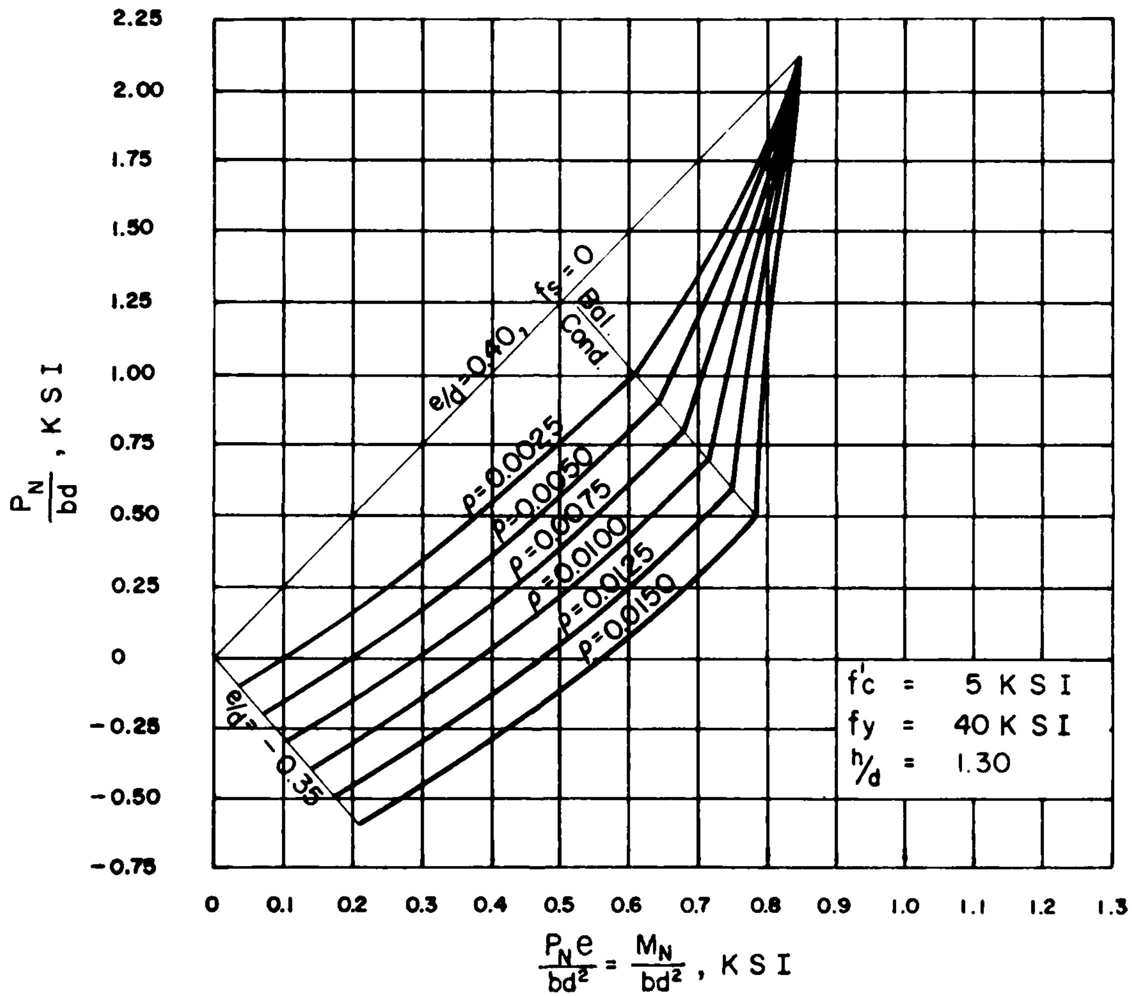


Figure 25. Load-moment strength interaction diagram for single reinforced members (f'_c = 5 ksi, f_y = 40 ksi, and h/d = 1.30)

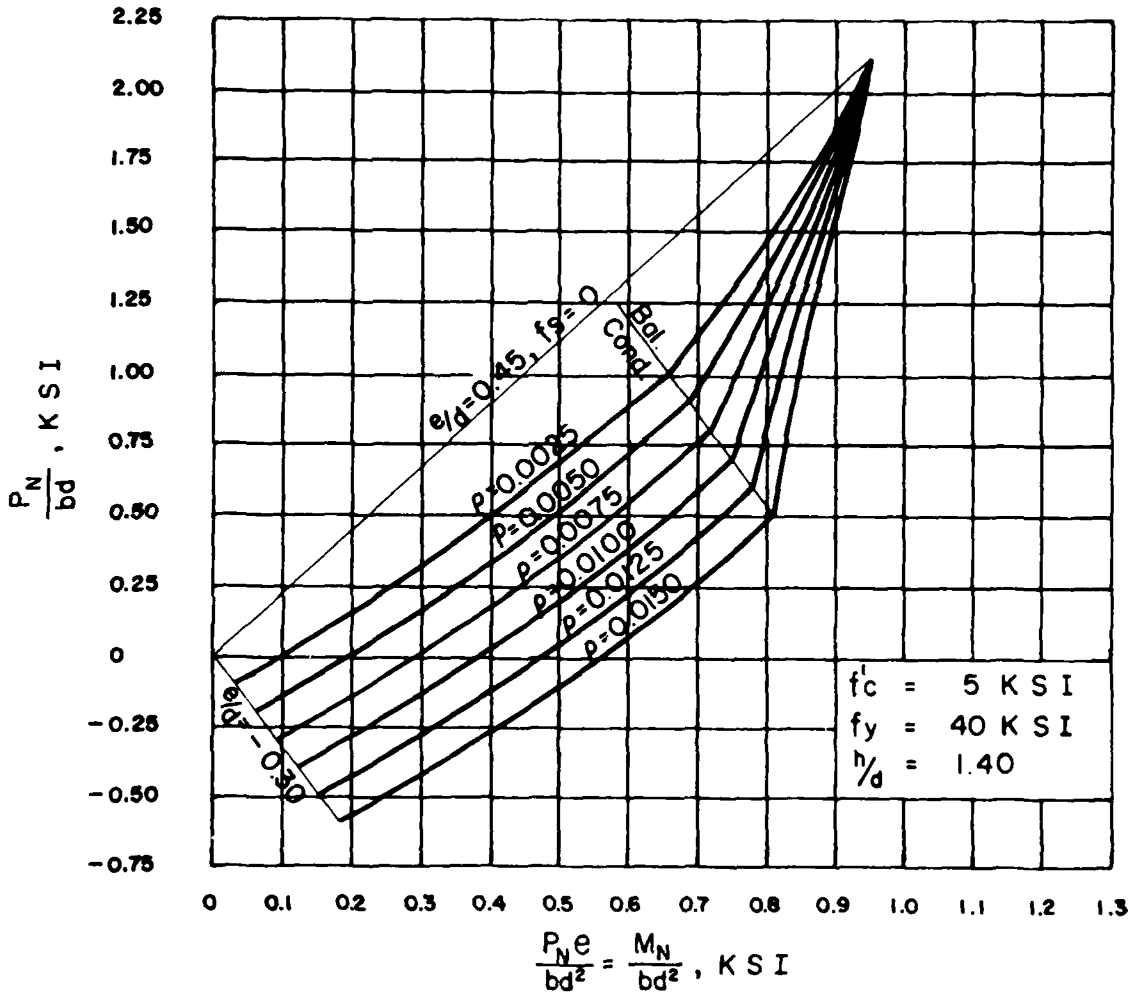


Figure 26. Load-moment strength interaction diagram for single reinforced members (f'_c = 5 ksi, f_y = 40 ksi, and h/d = 1.40)

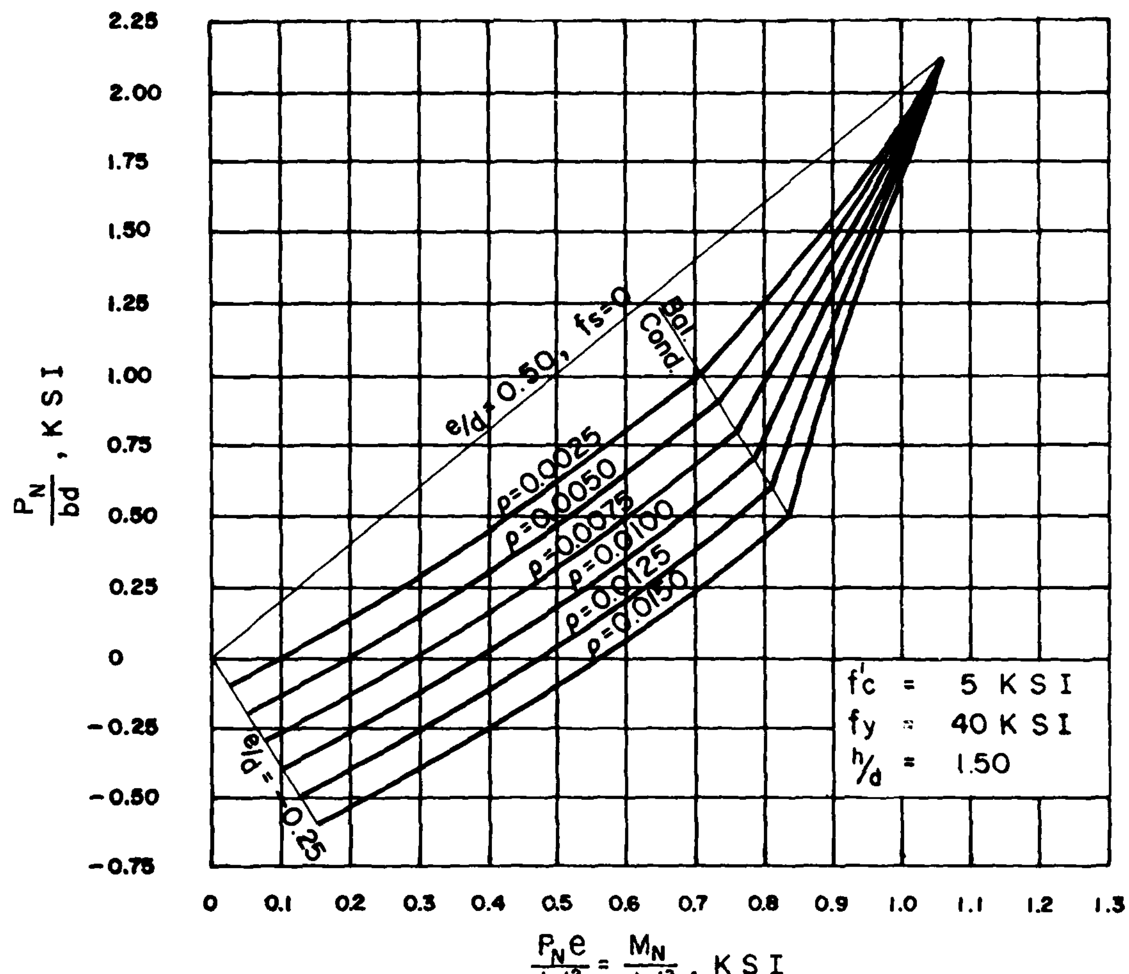


Figure 27. Load-moment strength interaction diagram for single reinforced members (f'_c = 5 ksi, f_y = 40 ksi, and h/d = 1.50)

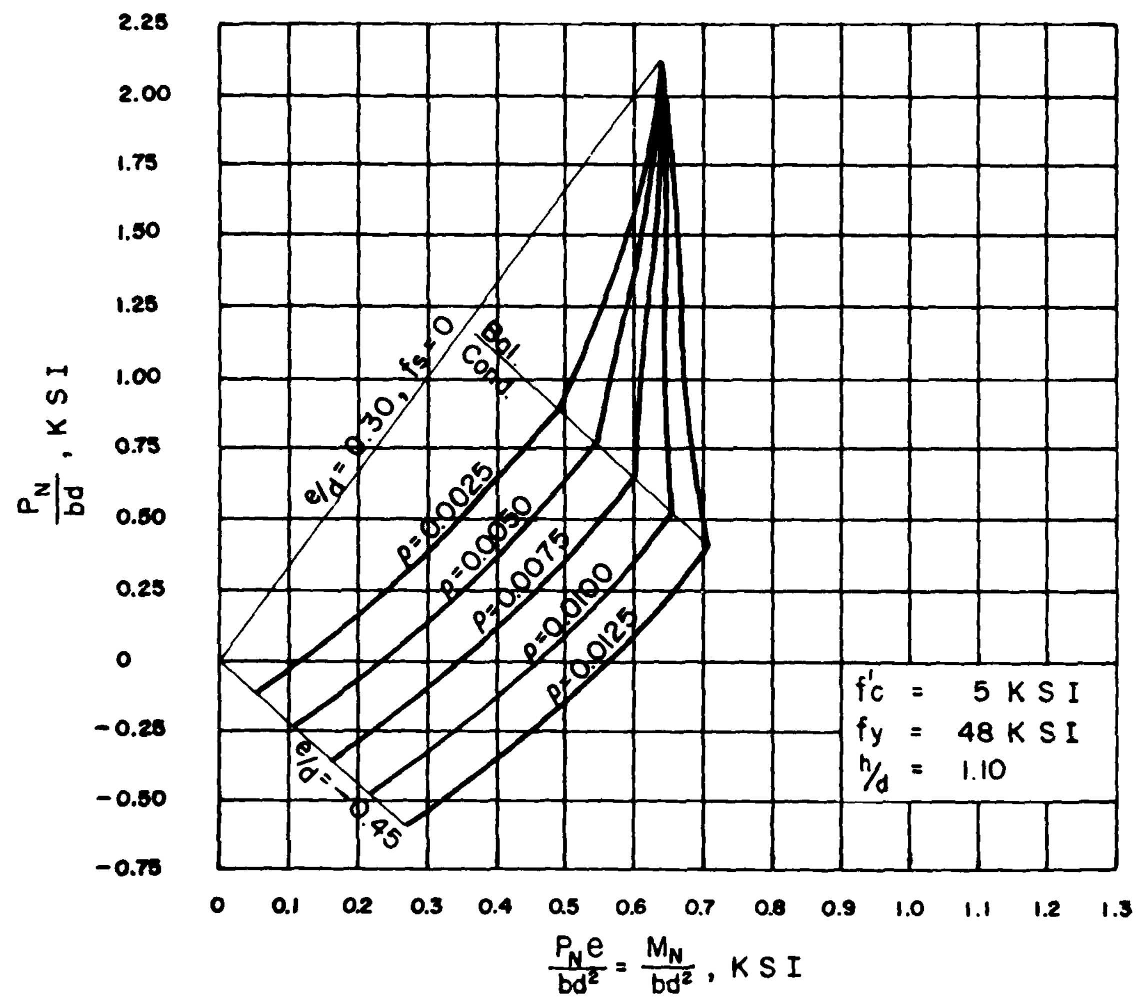


Figure 28. Load-moment strength interaction diagram for single reinforced members (f'_c = 5 ksi, f_y = 48 ksi, and h/d = 1.10)

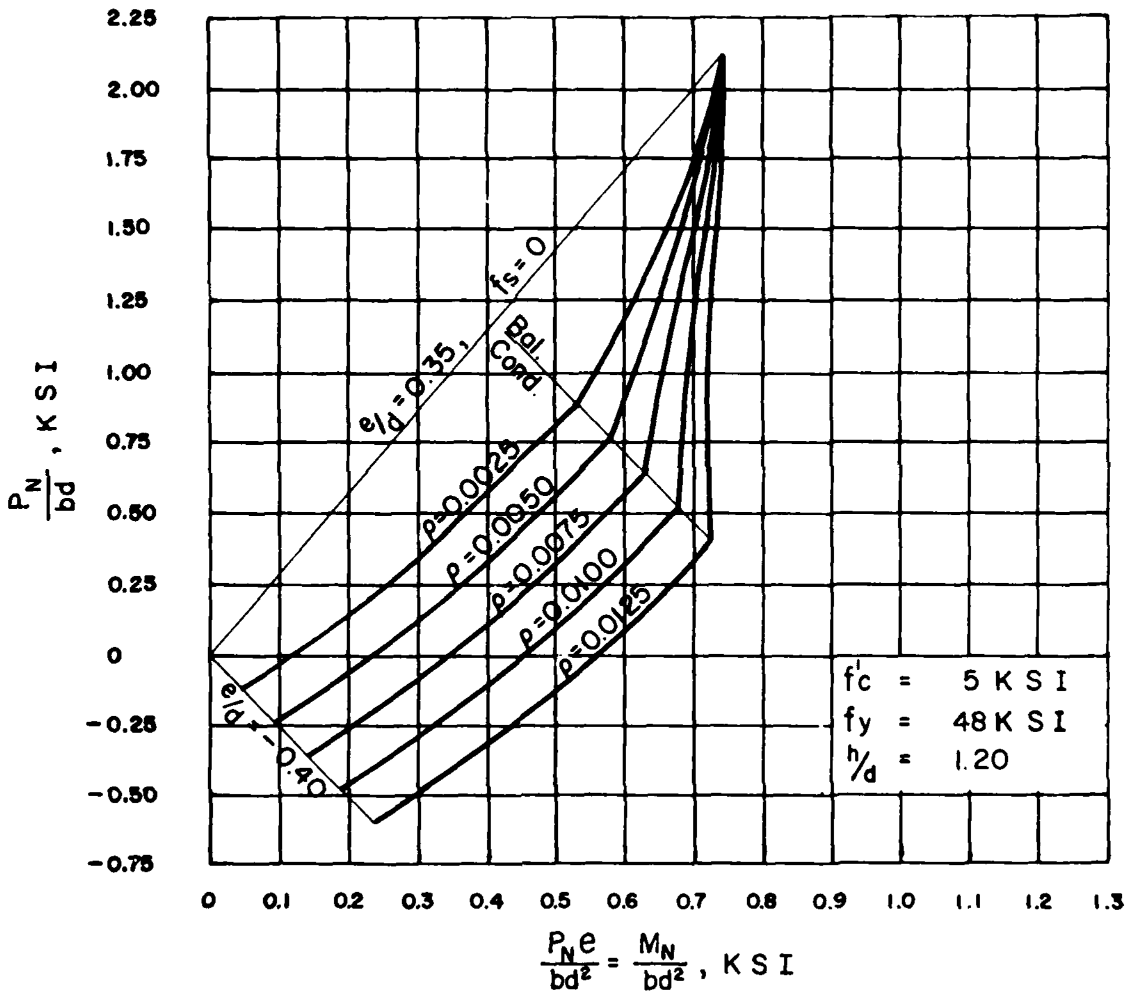


Figure 29. Load-moment strength interaction diagram for single reinforced members (f'_c = 5 ksi, f_y = 48 ksi, and h/d = 1.20)

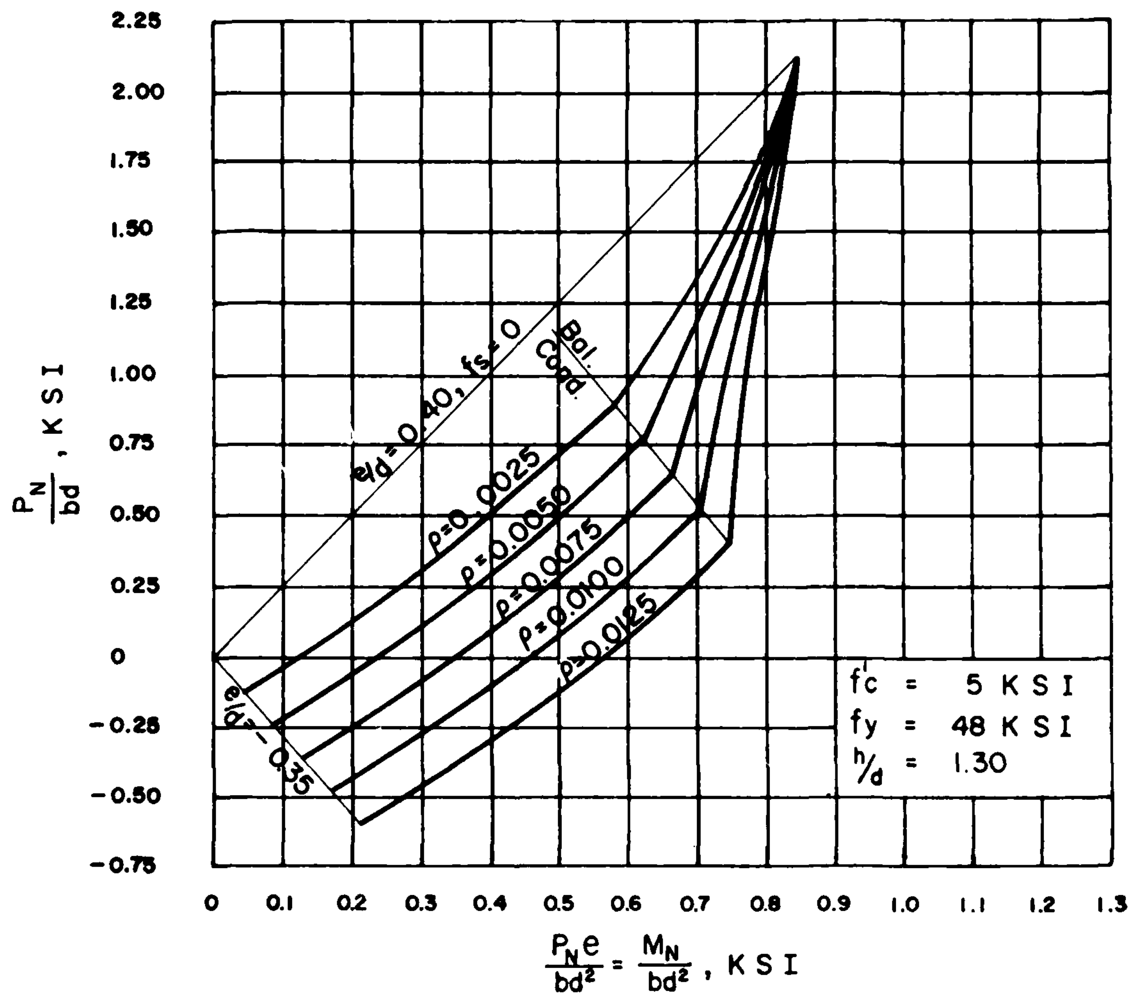


Figure 30. Load-moment strength interaction diagram for single reinforced members (f'_c = 5 ksi, f_y = 48 ksi, and h/d = 1.30)

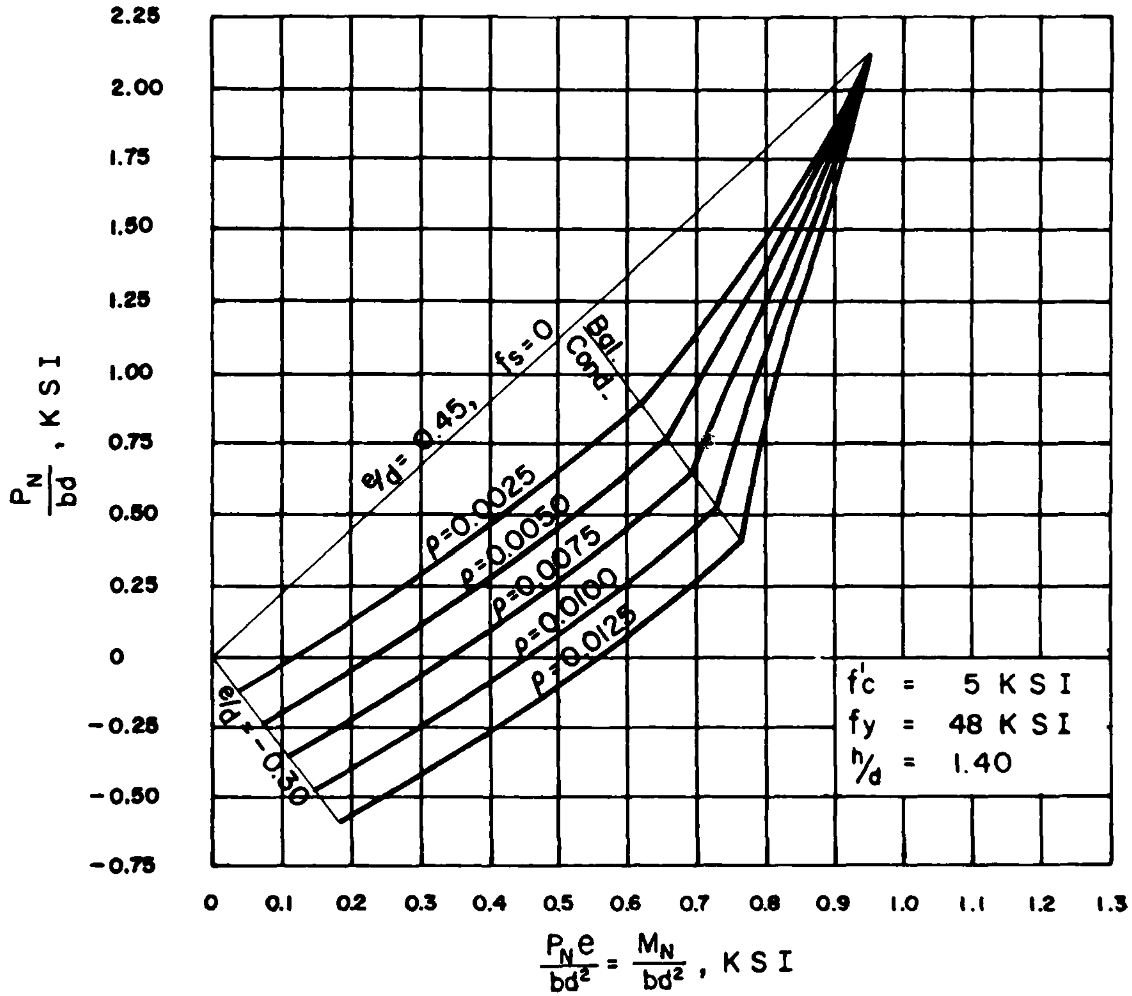


Figure 31. Load-moment strength interaction diagram for single reinforced members (f'_c = 5 ksi, f_y = 48 ksi, and h/d = 1.40)

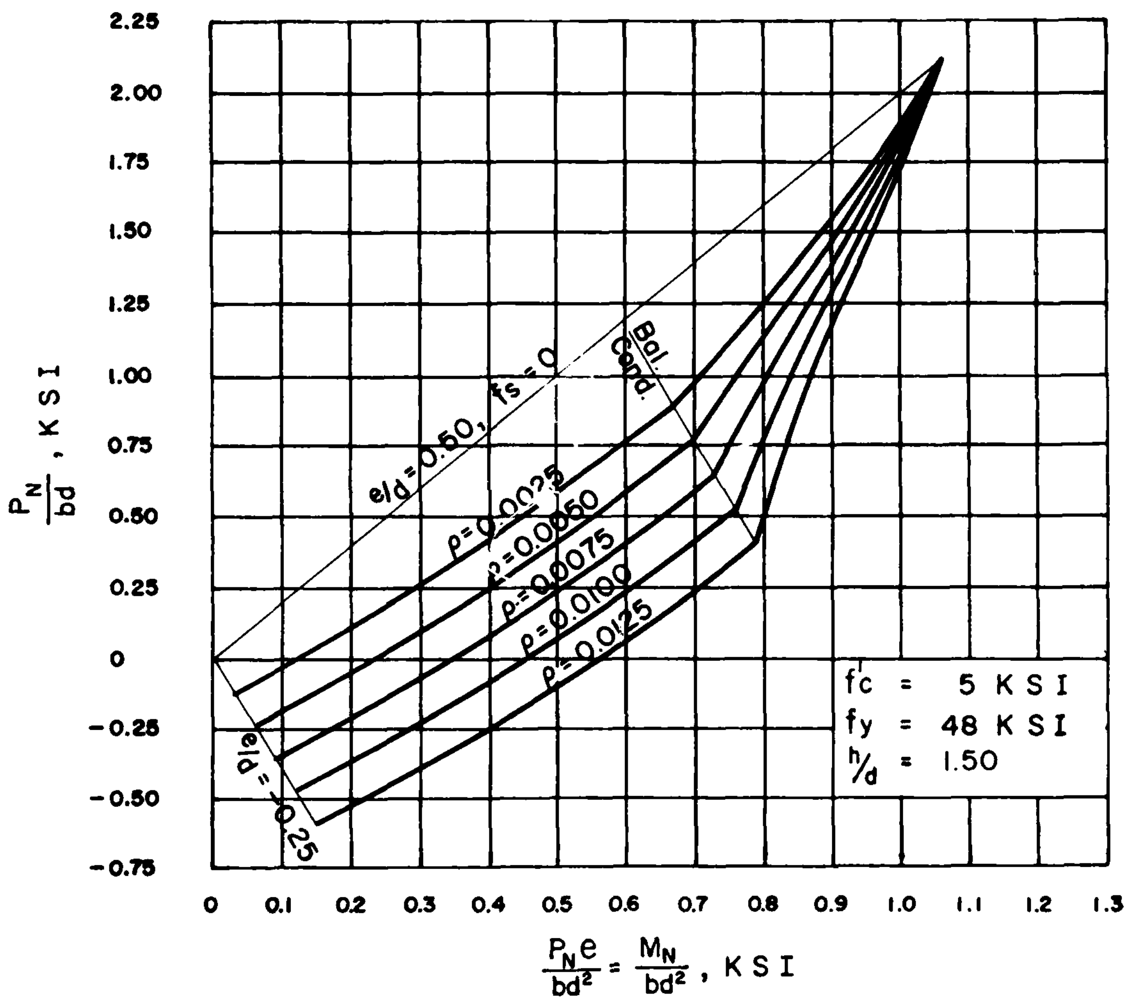


Figure 32. Load-moment strength interaction diagram for single reinforced members (f'_c = 5 ksi, f_y = 48 ksi, and h/d = 1.50)

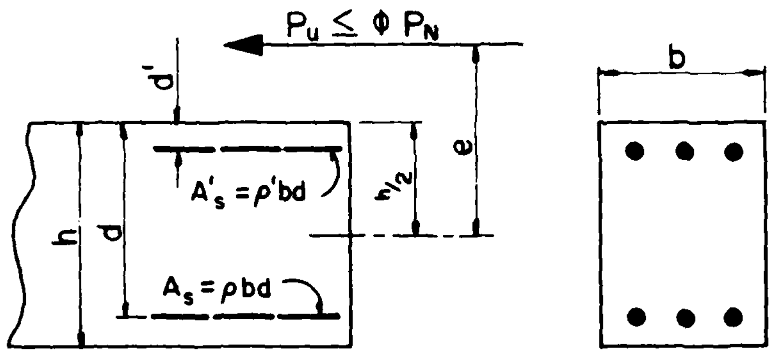


Figure 33. Notation and limitation, double reinforced members

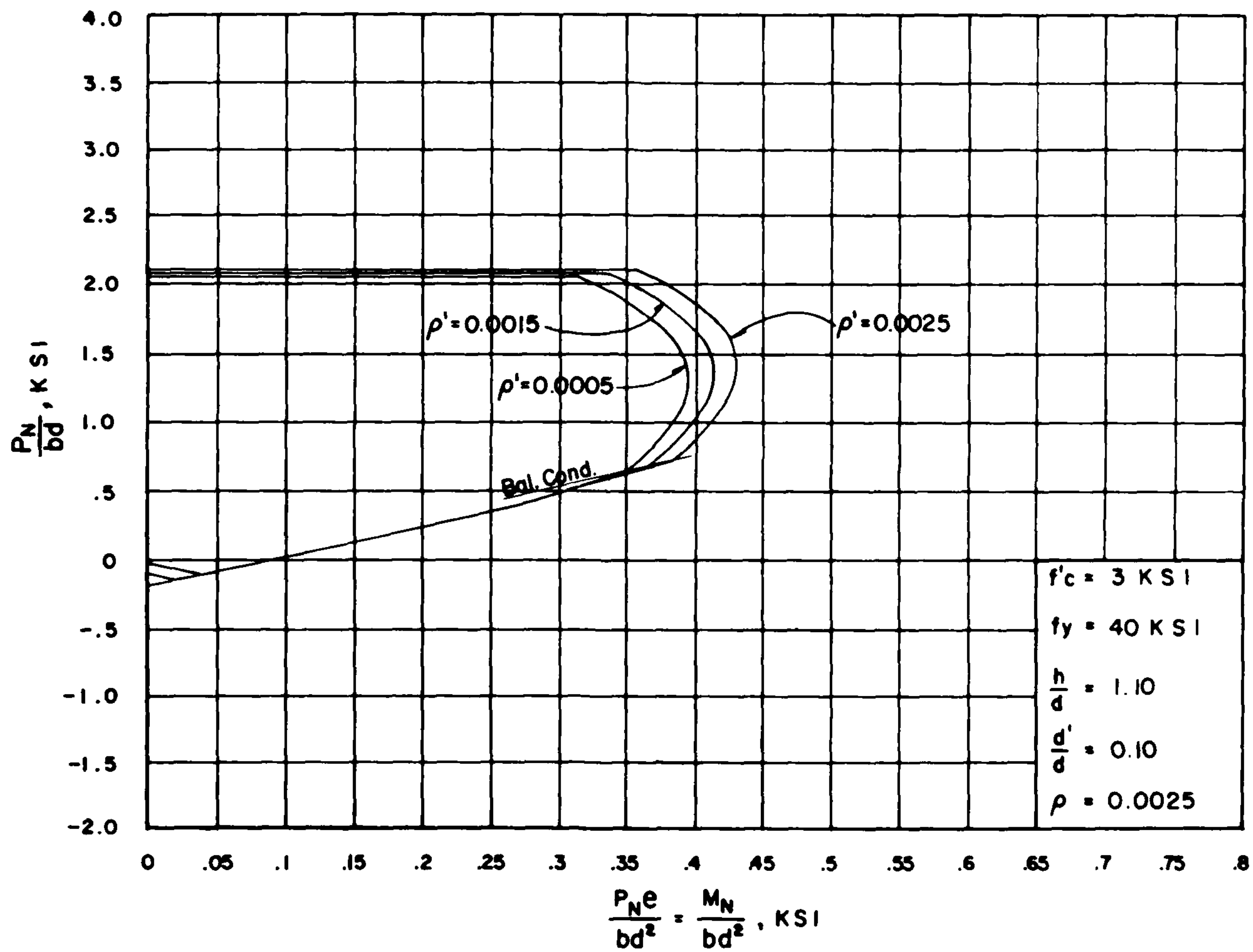


Figure 34. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0025)

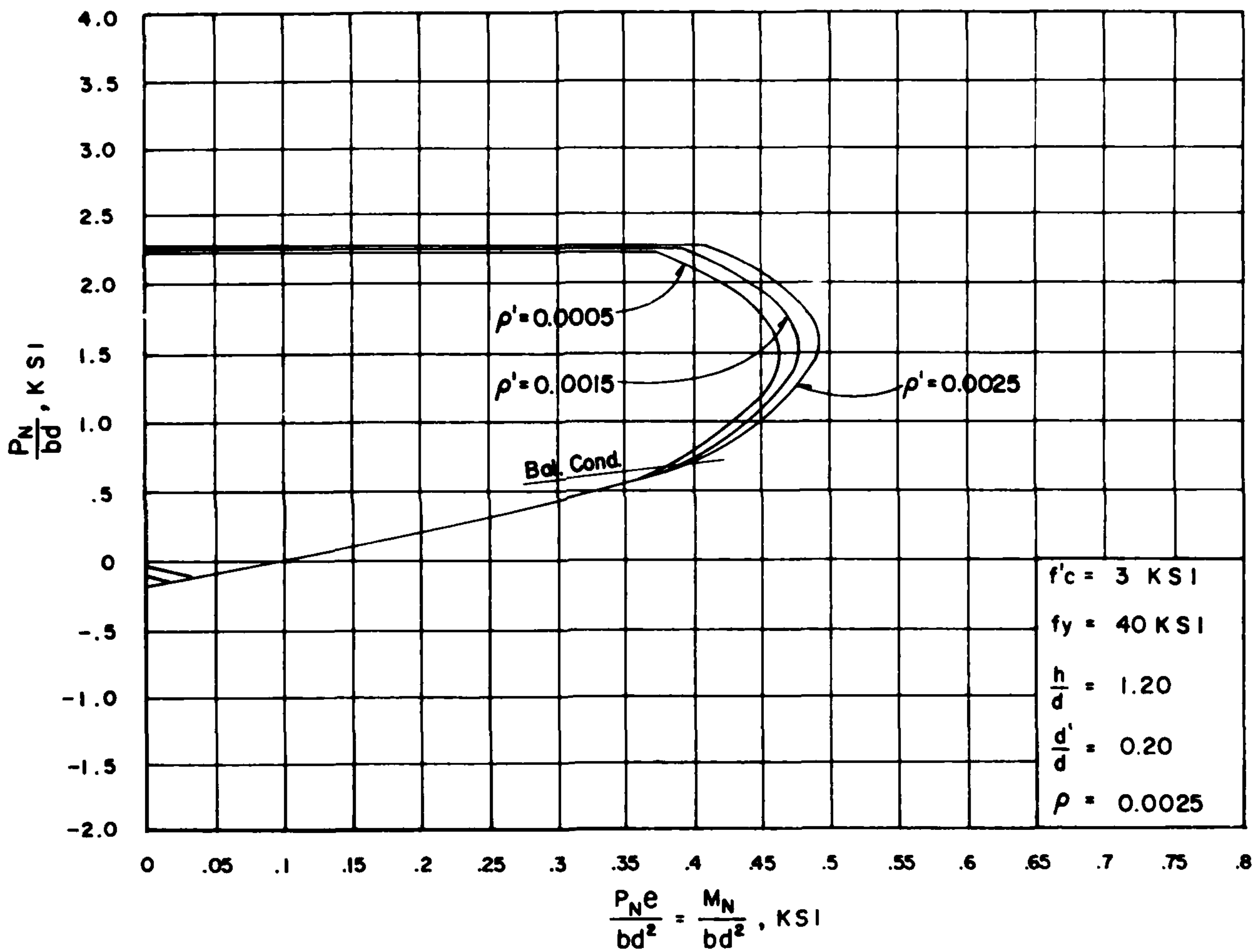


Figure 35. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0025)

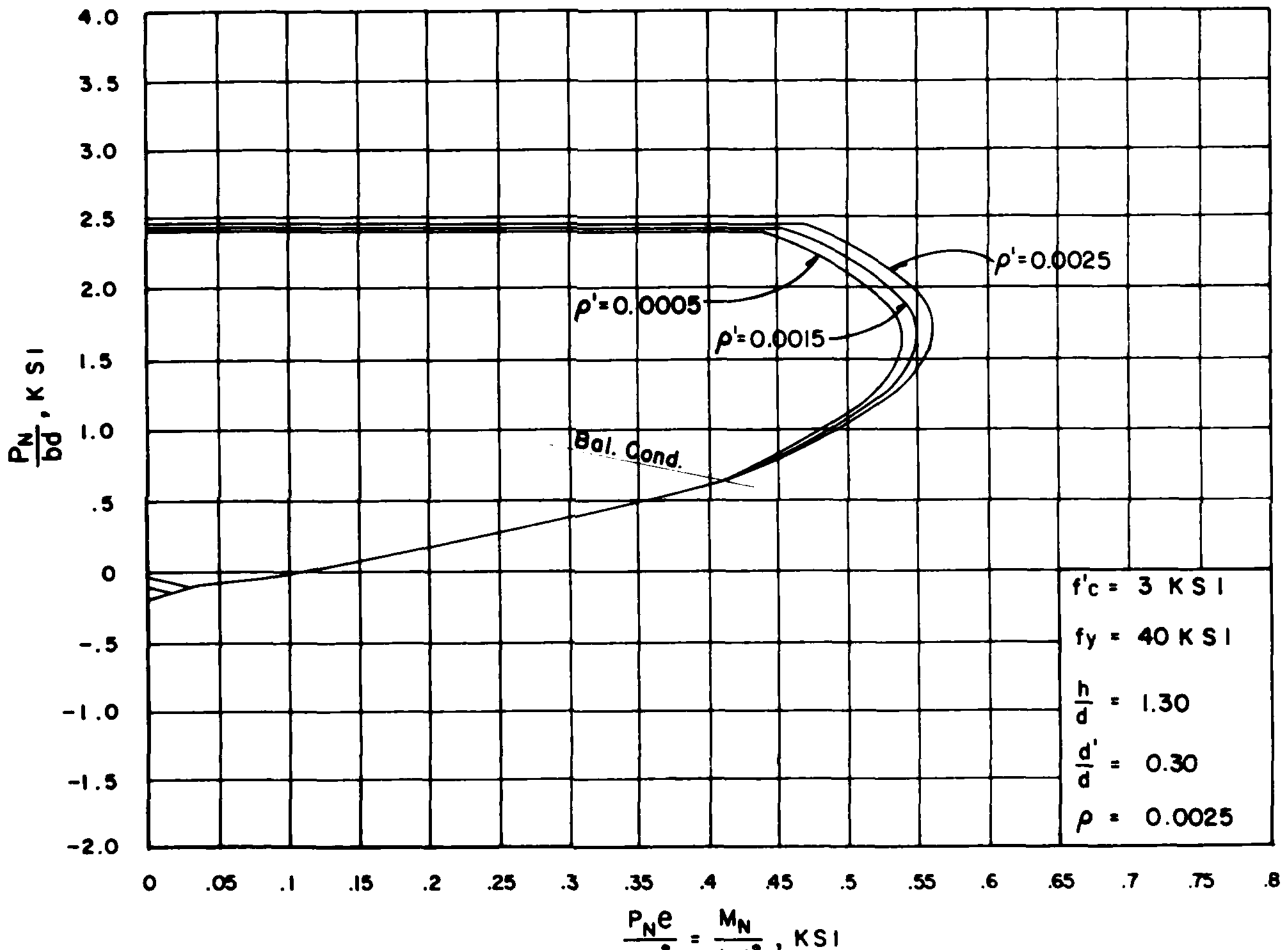


Figure 36. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0025)

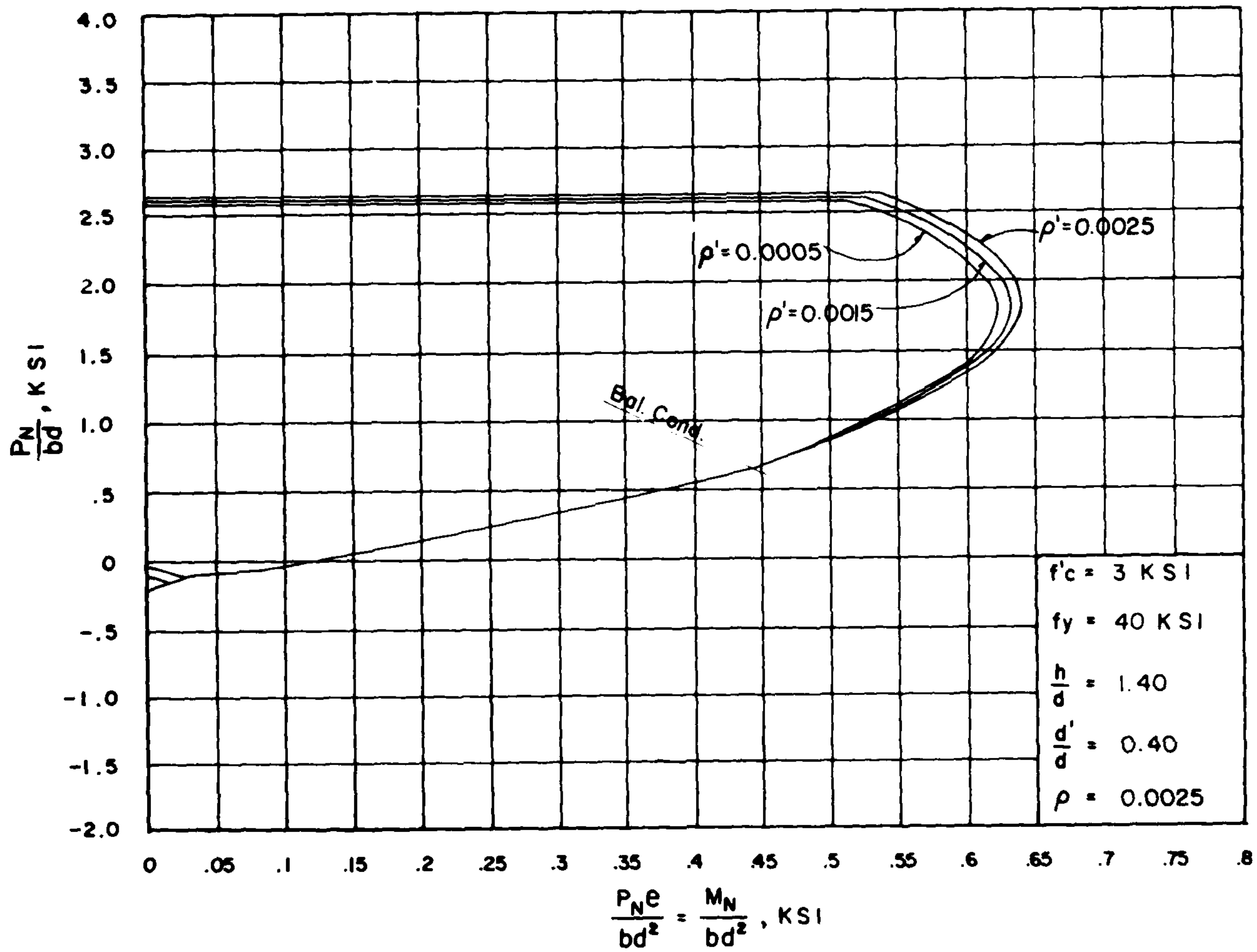


Figure 37. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0025)

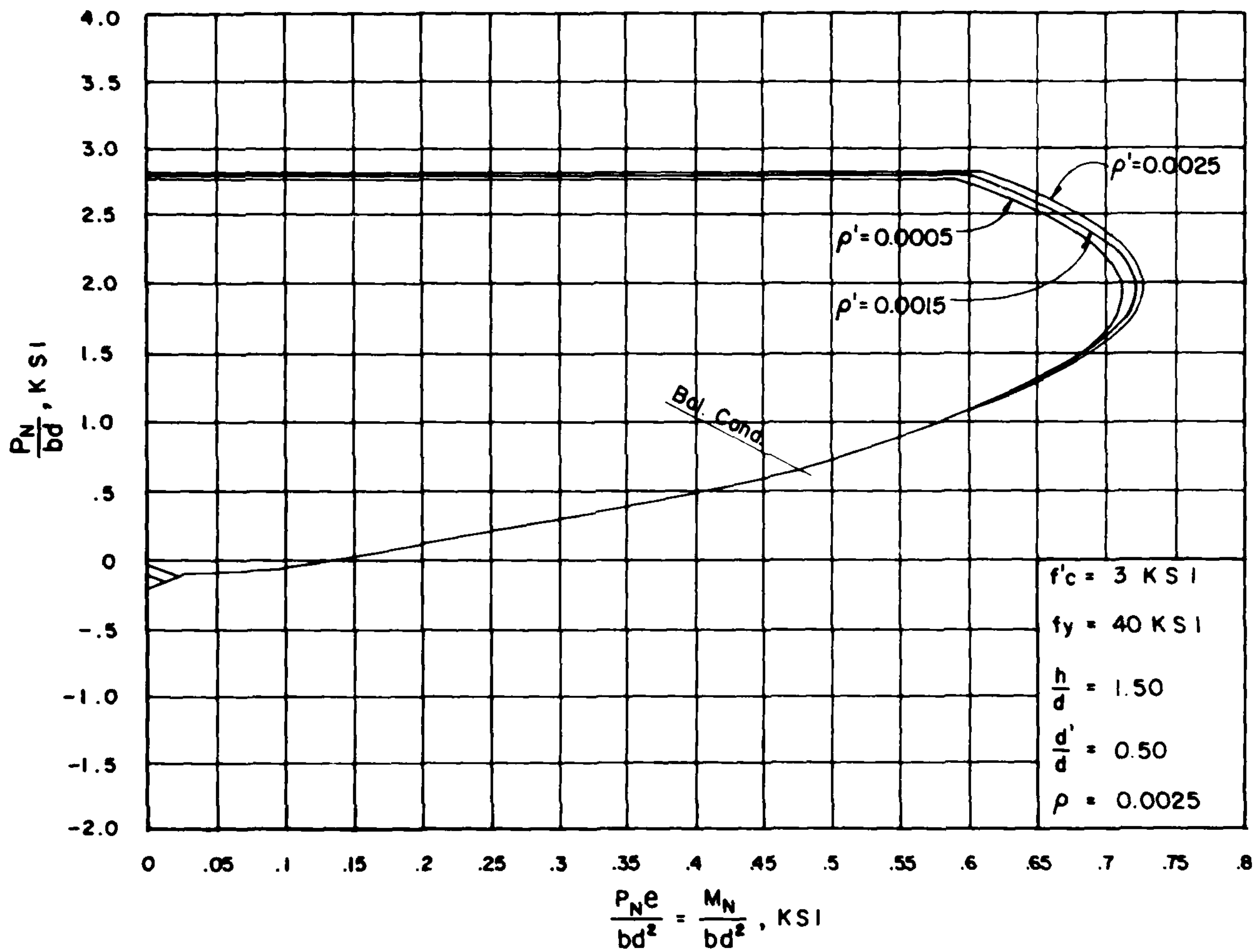


Figure 38. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0025)

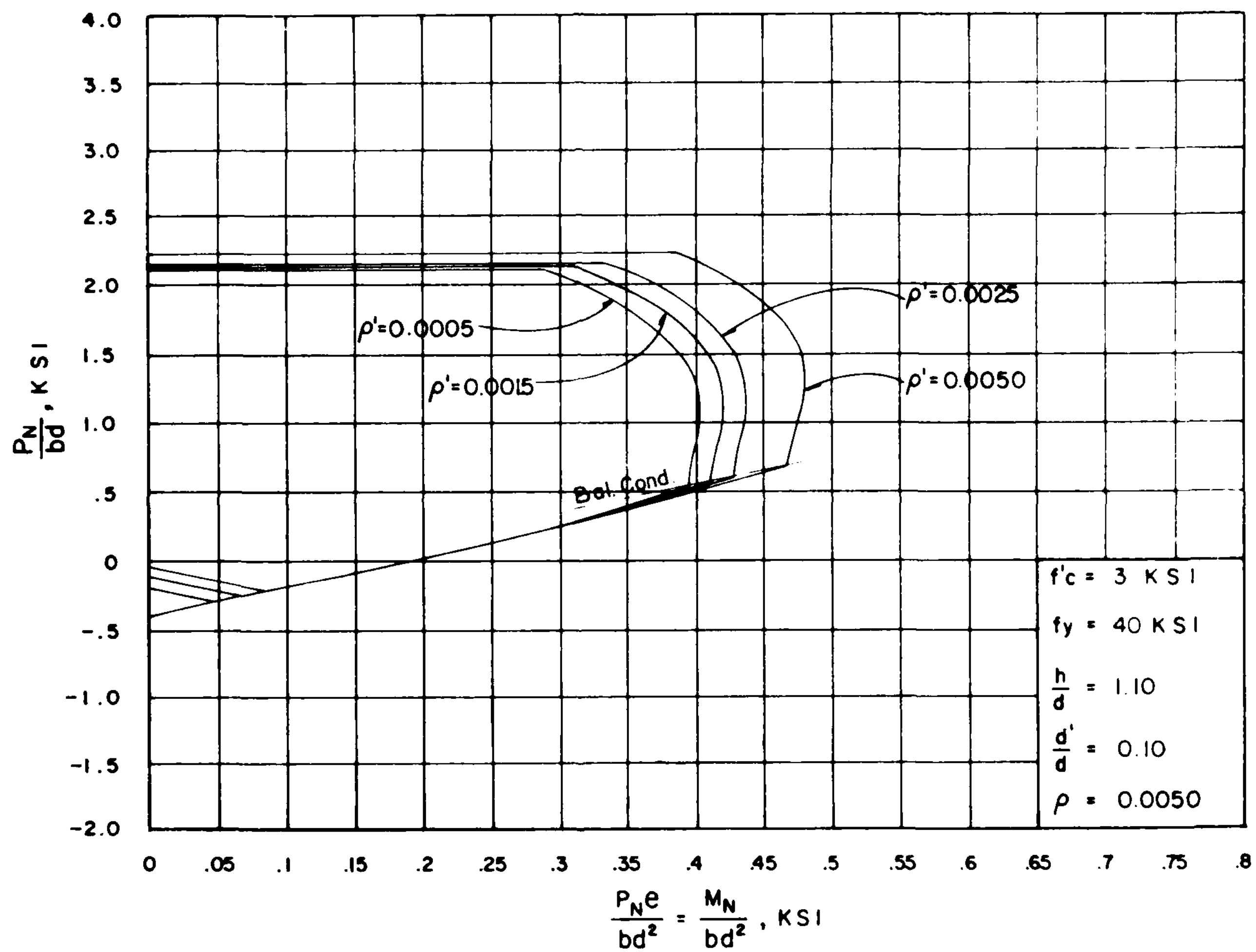


Figure 39. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0050)

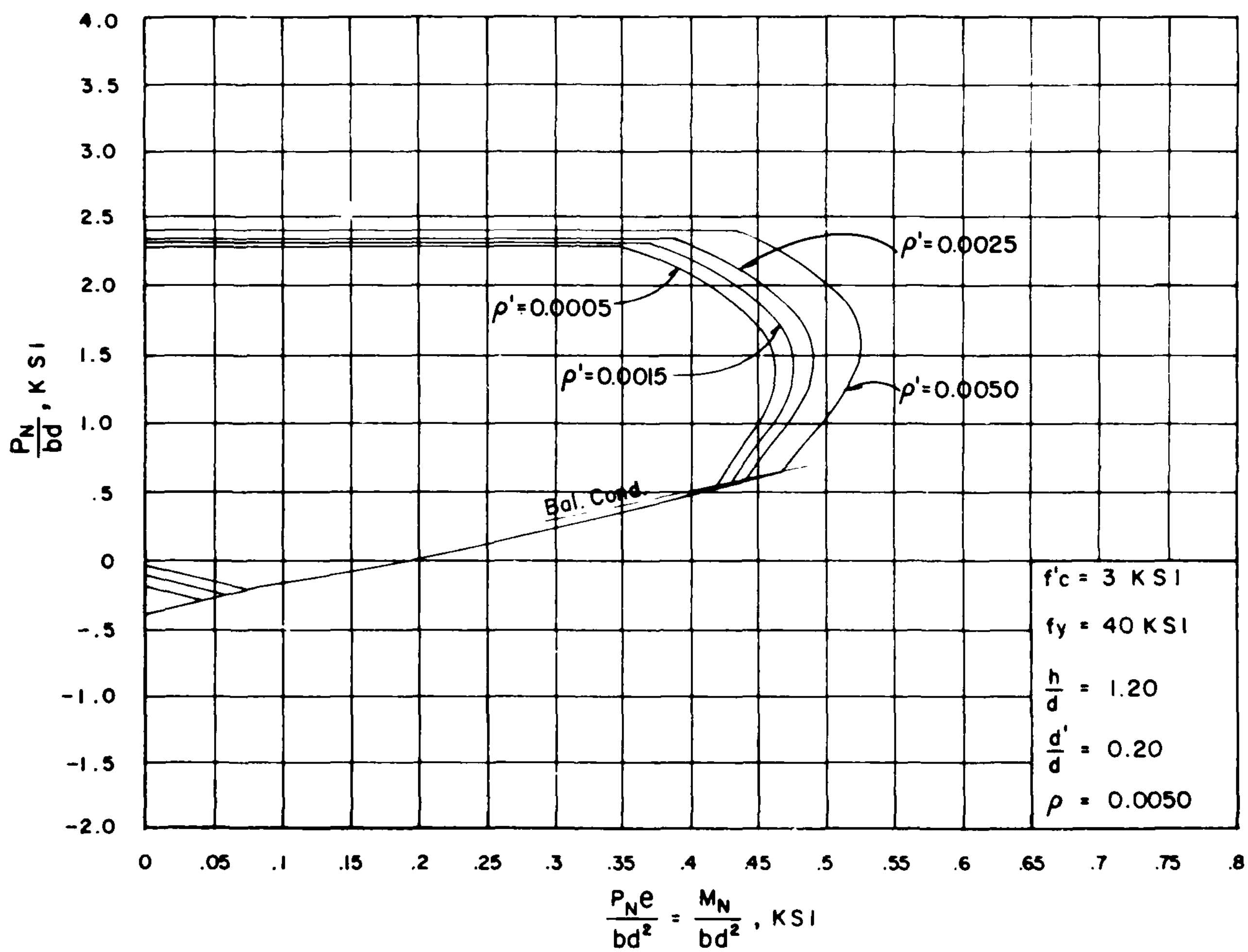


Figure 40. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0050)

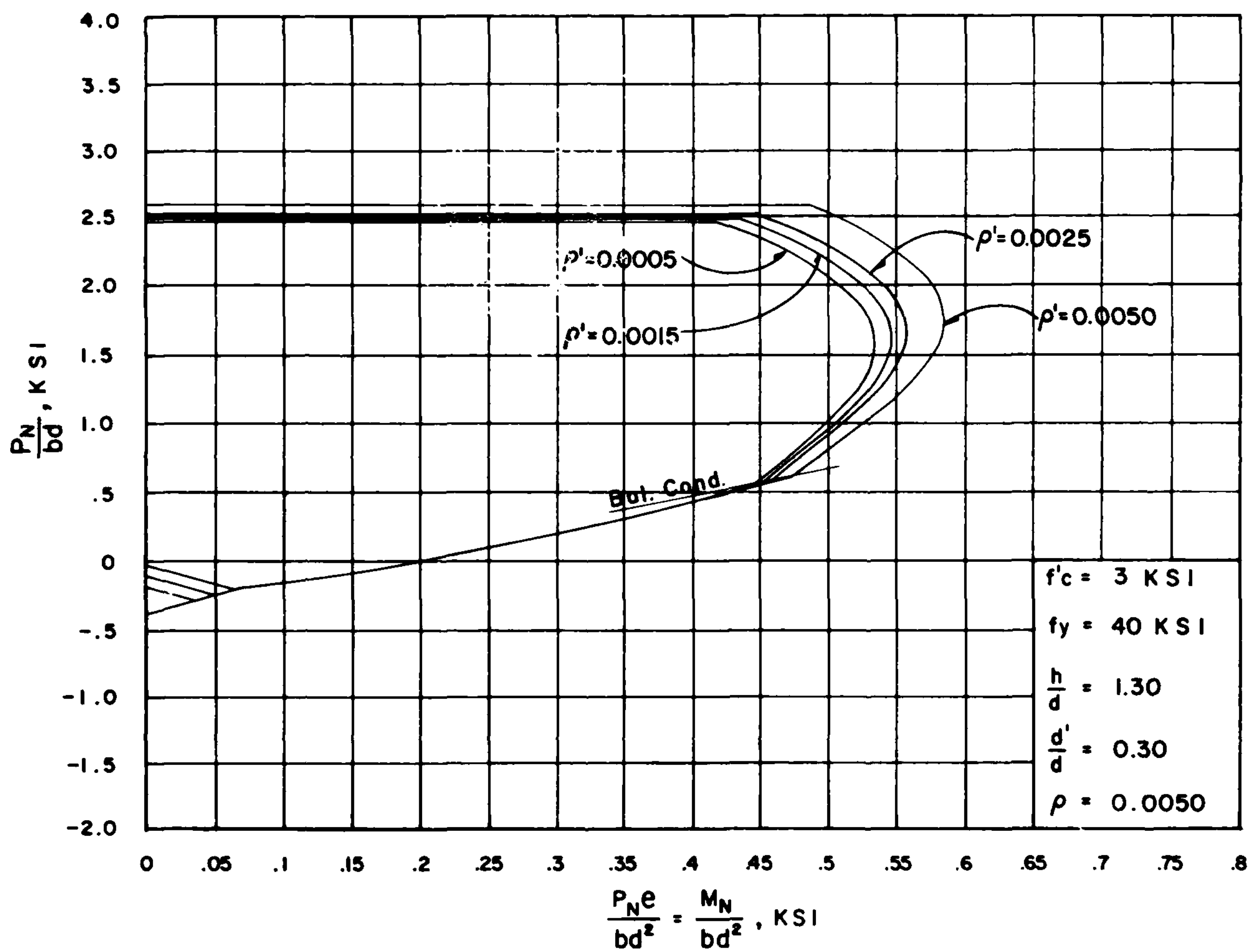


Figure 41. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0050)

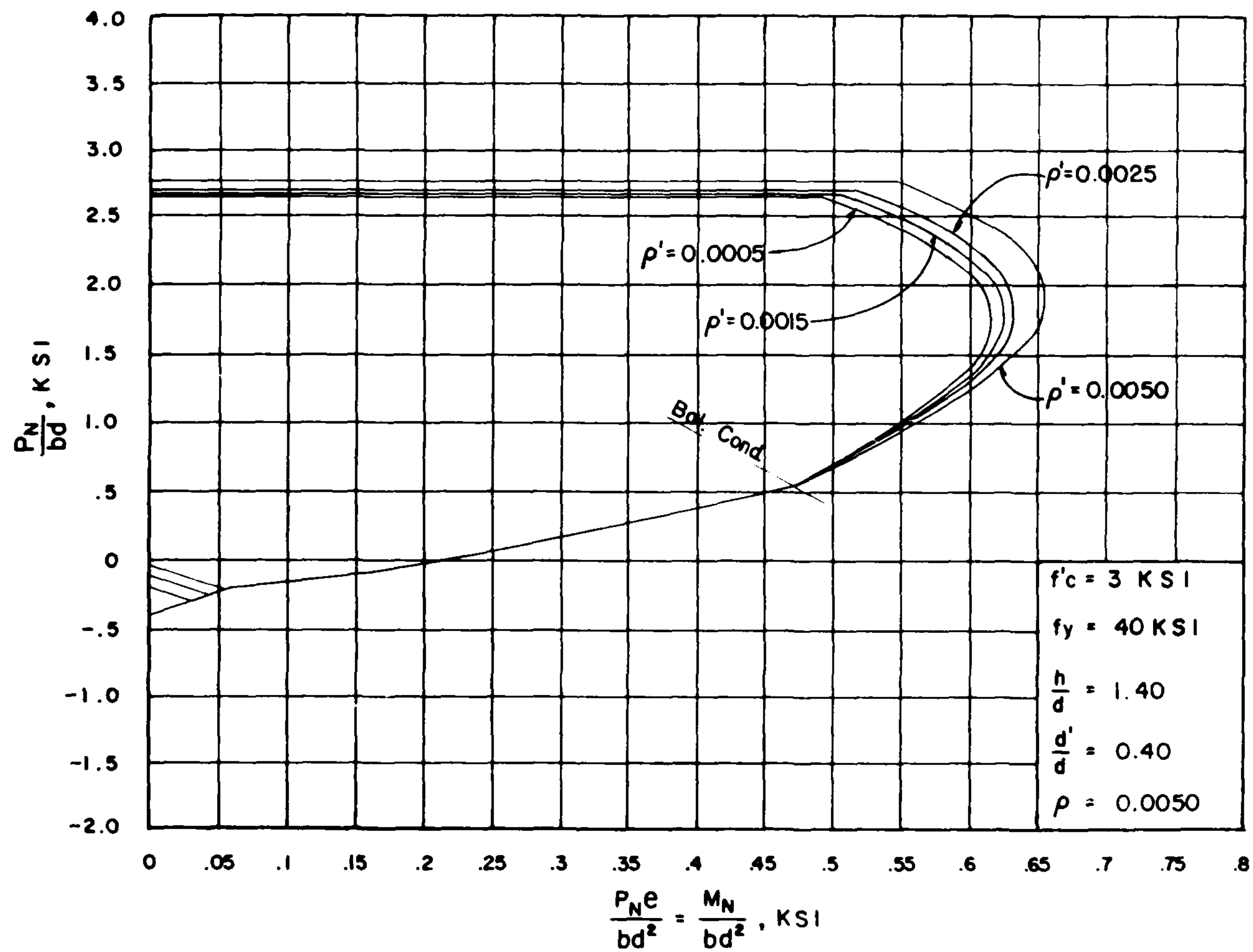


Figure 42. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0050)

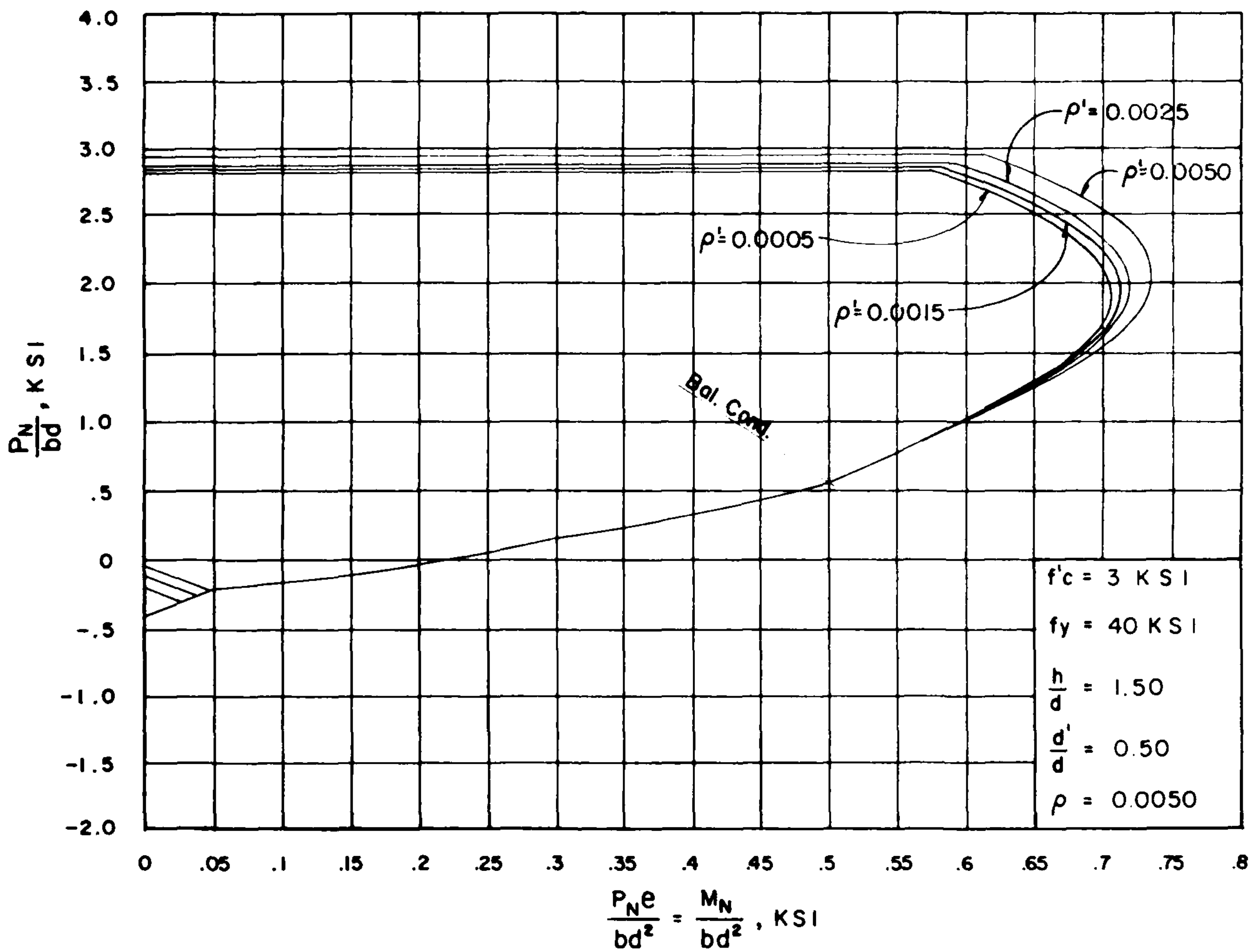


Figure 43. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0050)

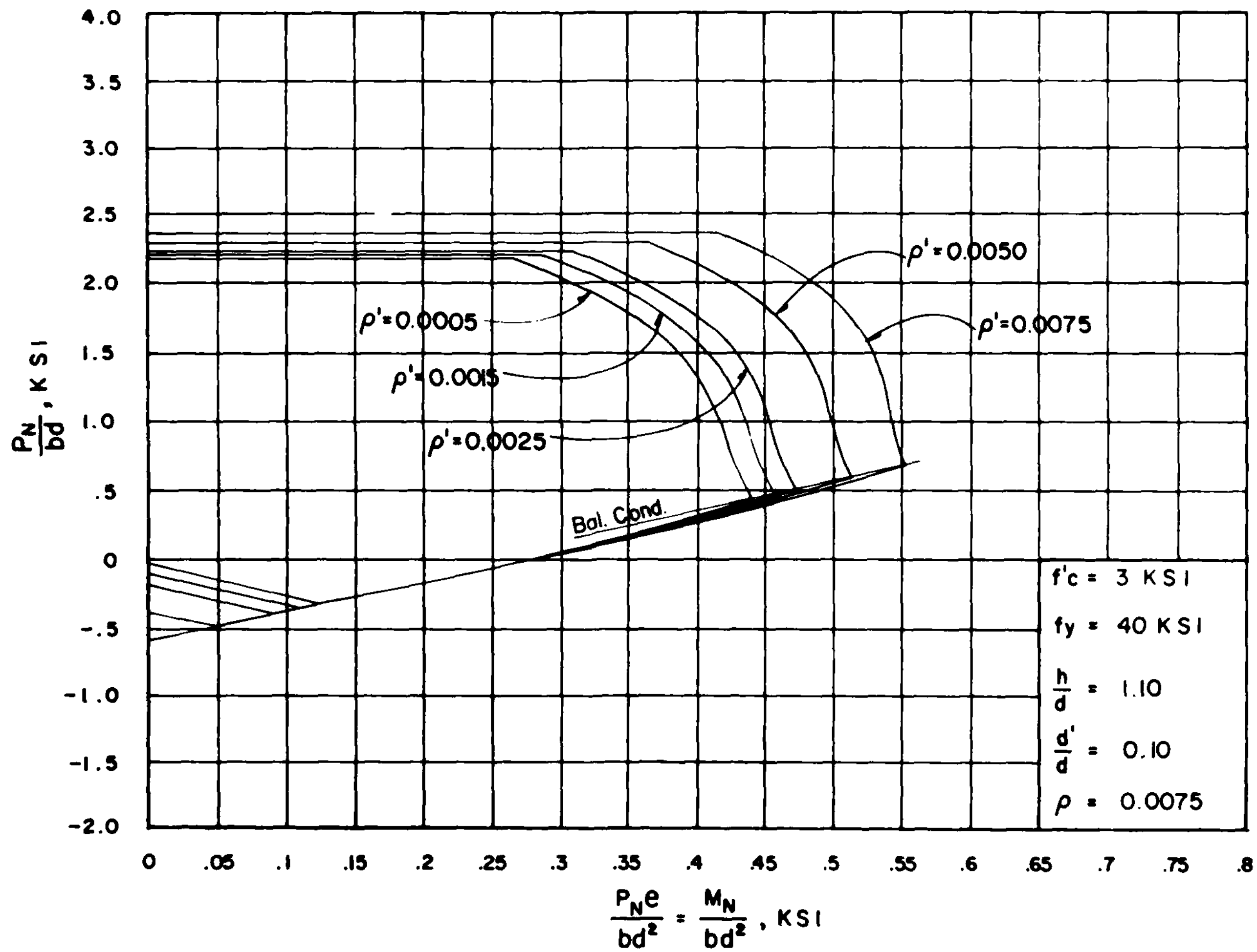


Figure 44. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0075)

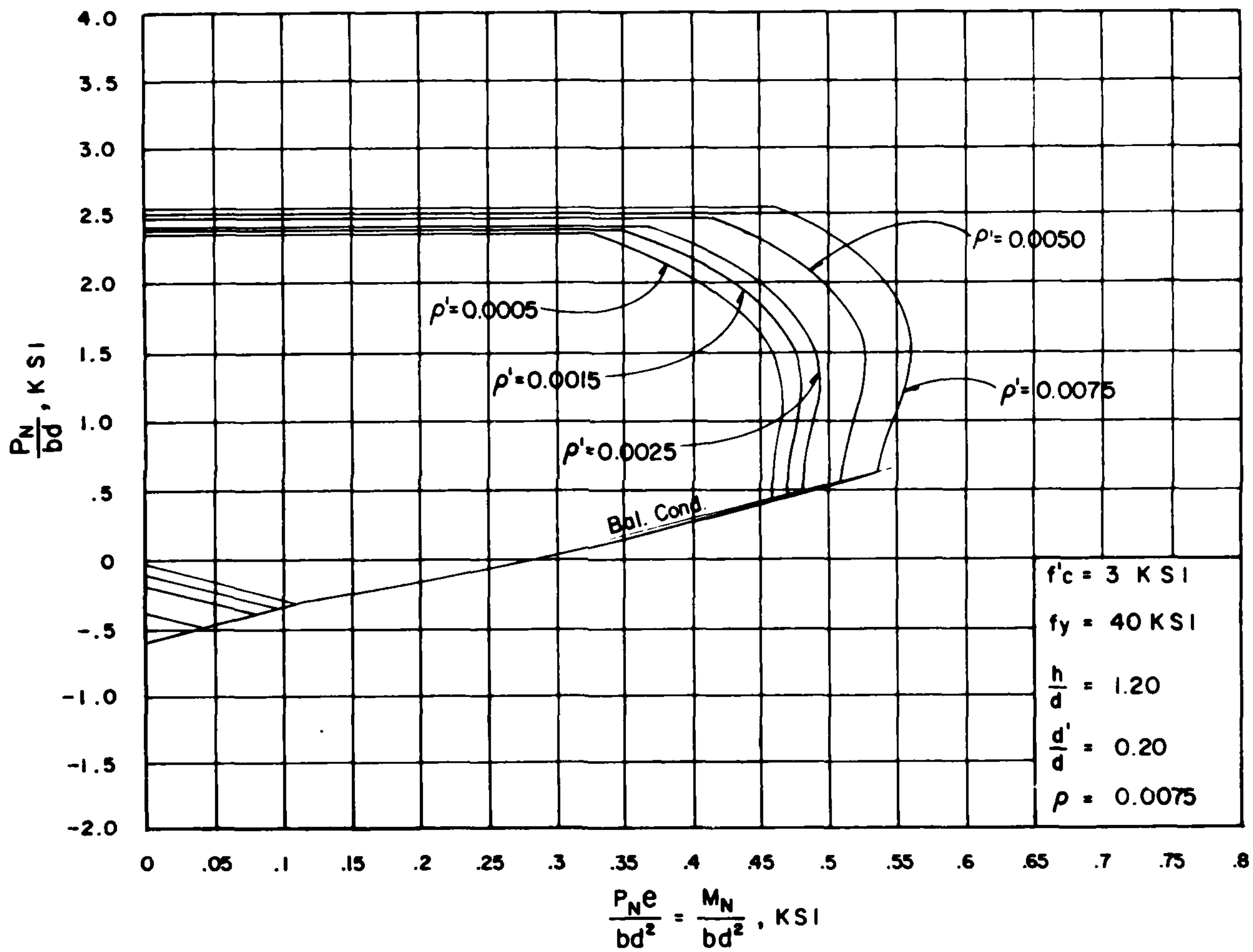


Figure 45. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0075)

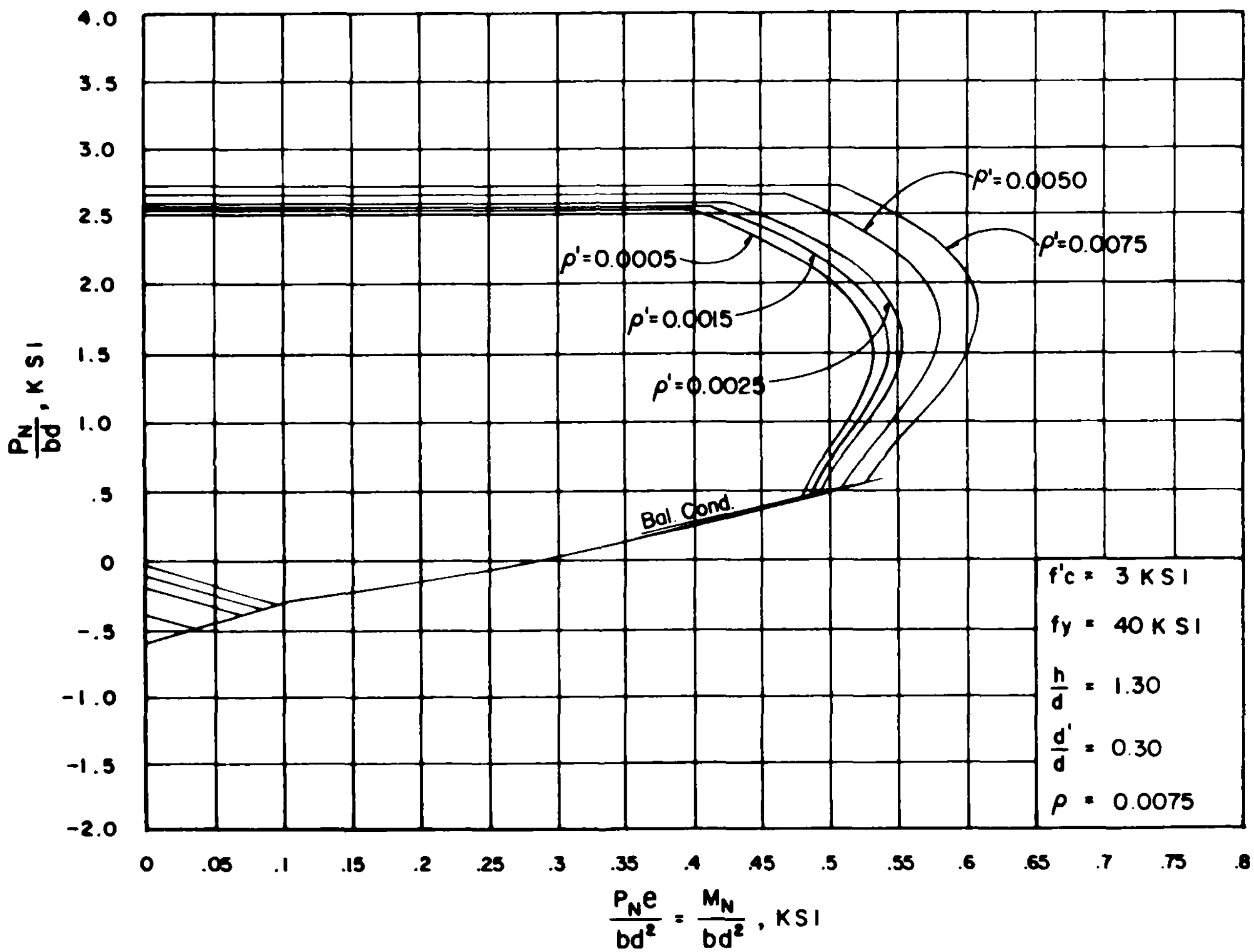


Figure 46. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0075)

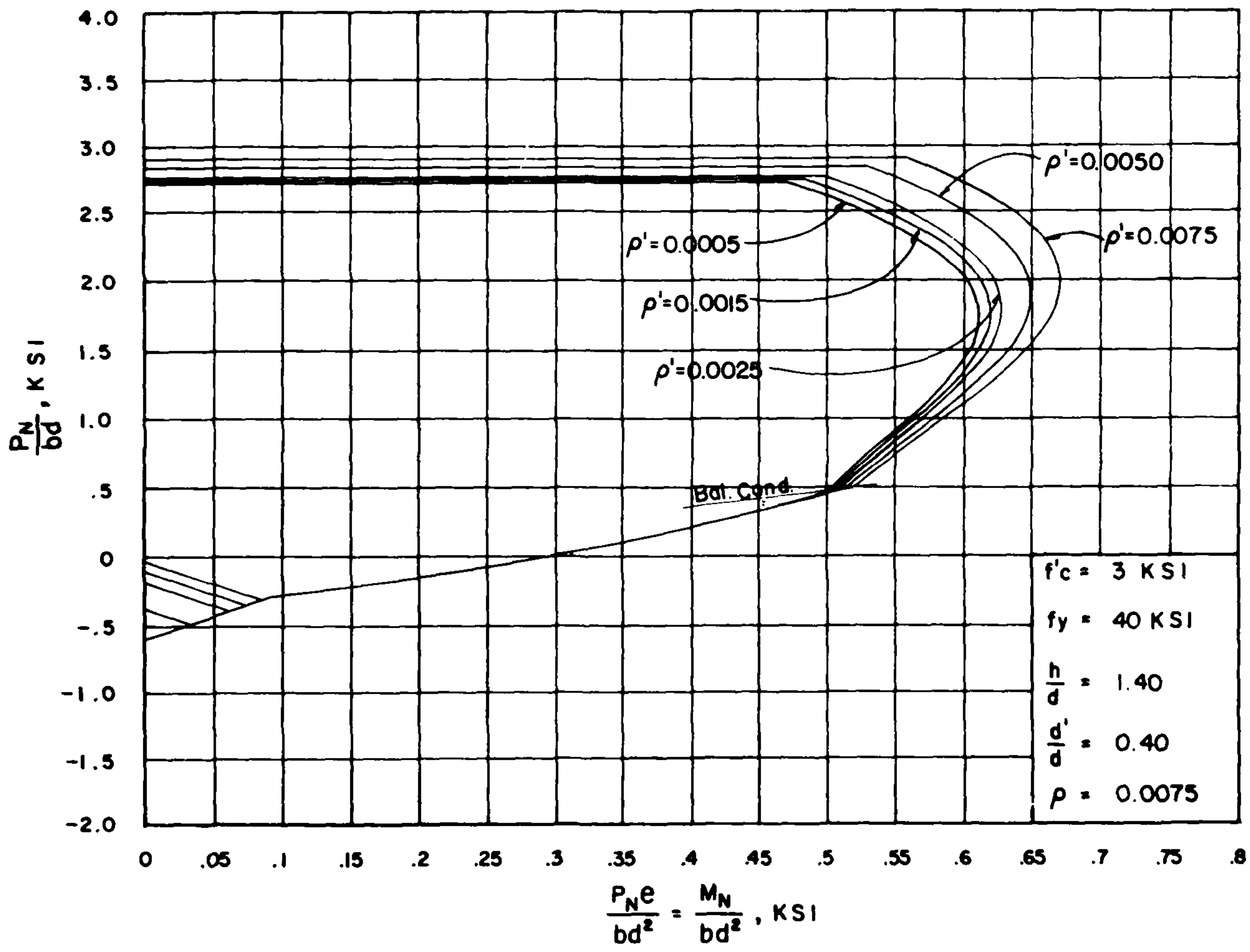


Figure 47. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0075)

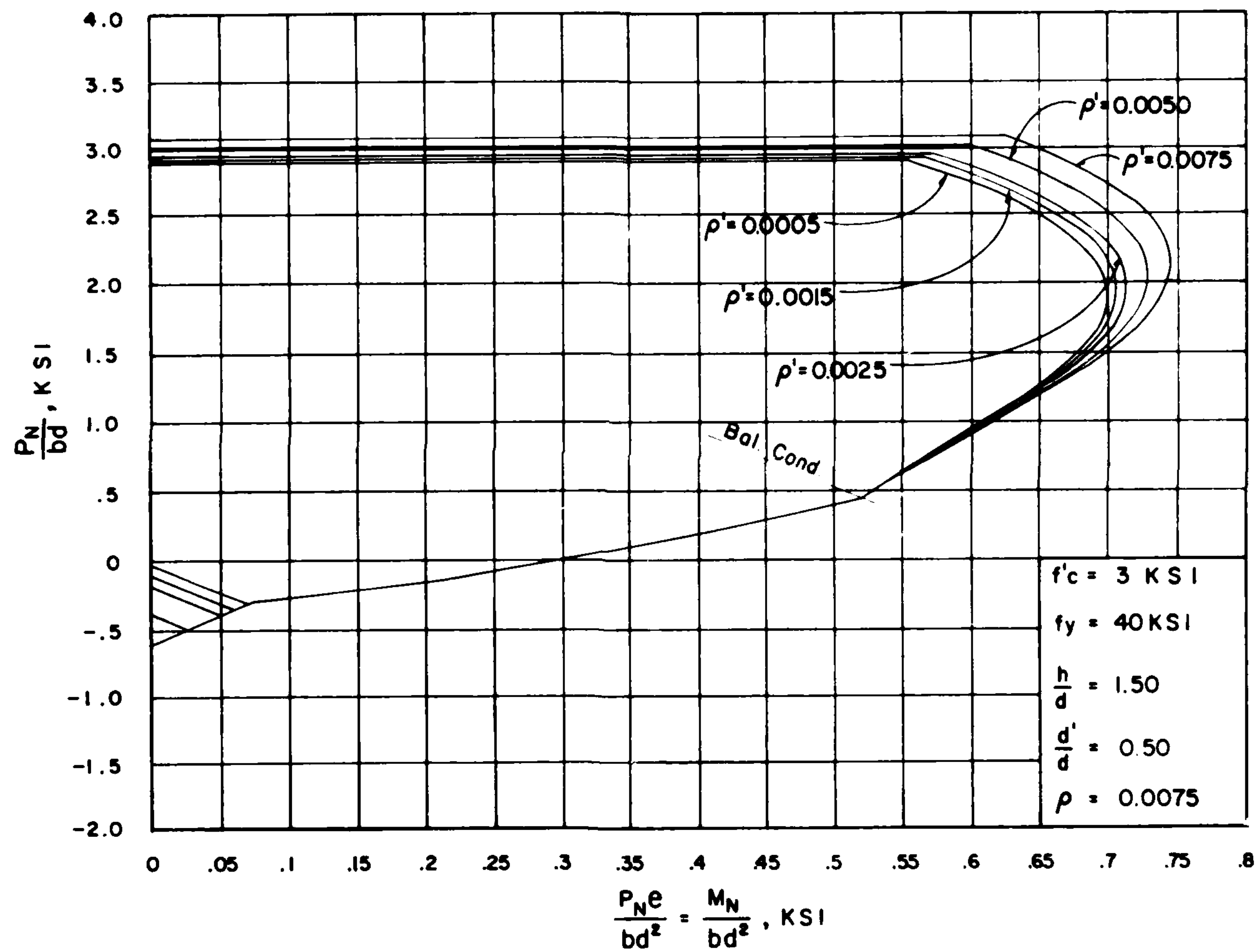


Figure 48. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0075)

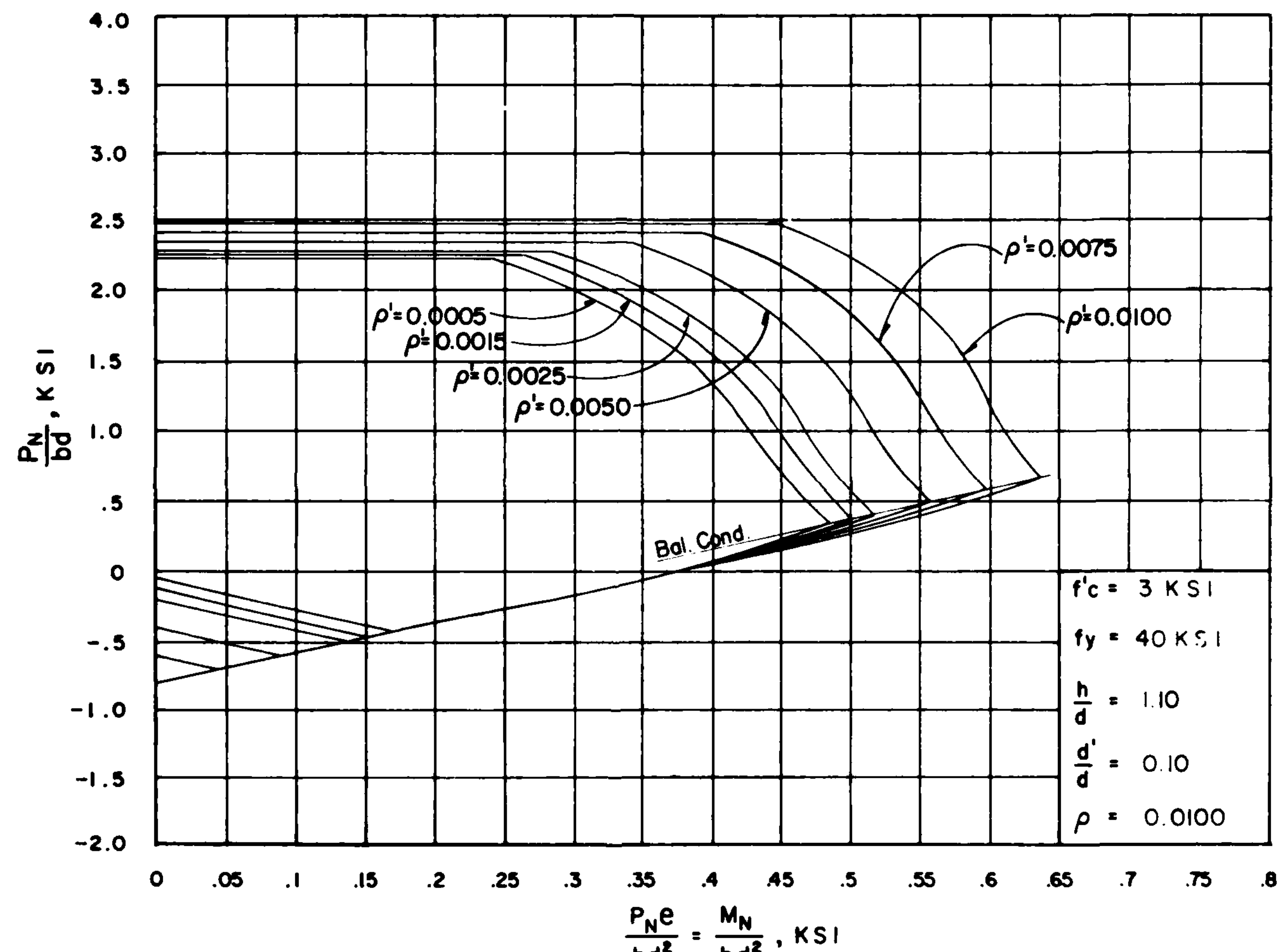


Figure 49. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0100)

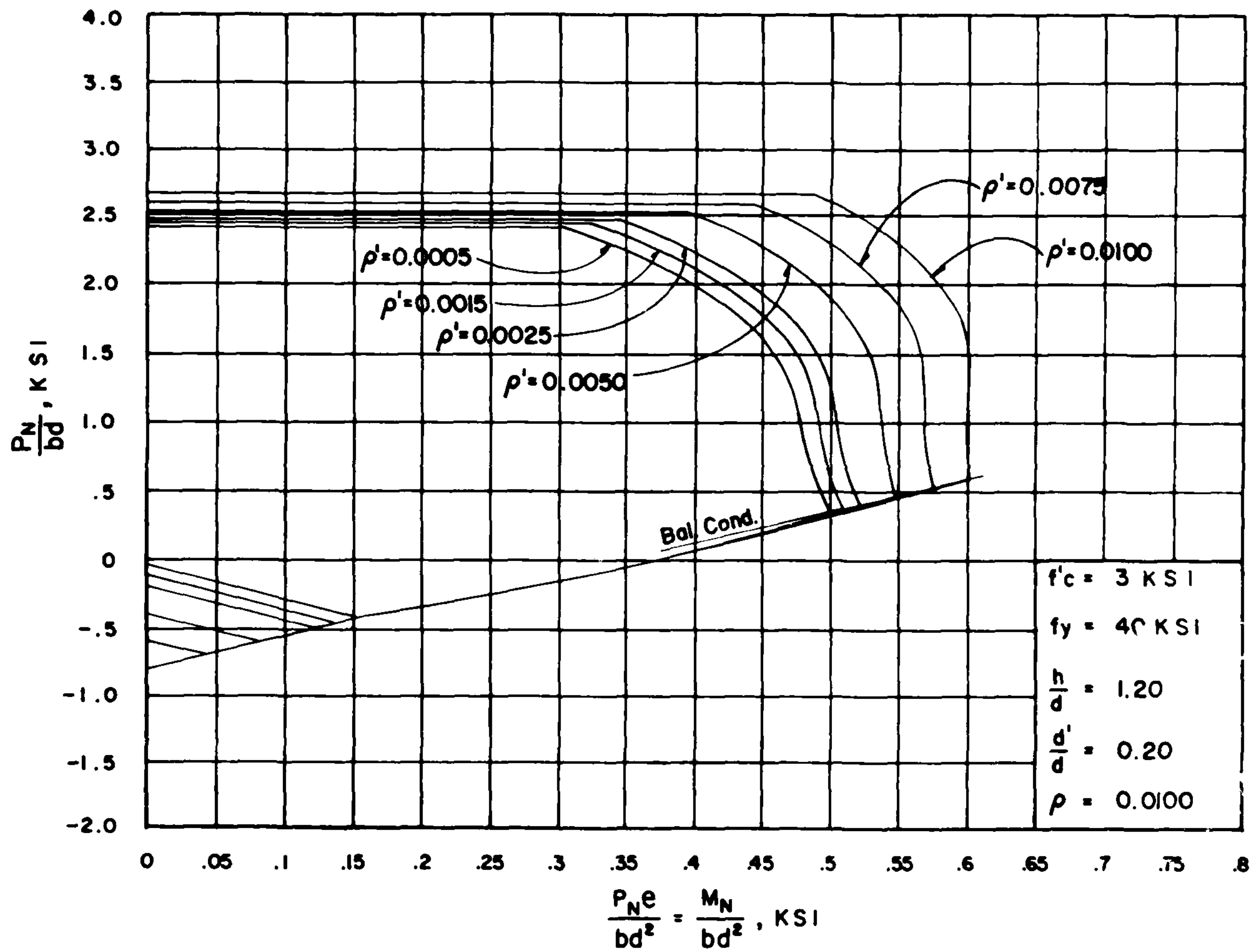


Figure 50. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0100)

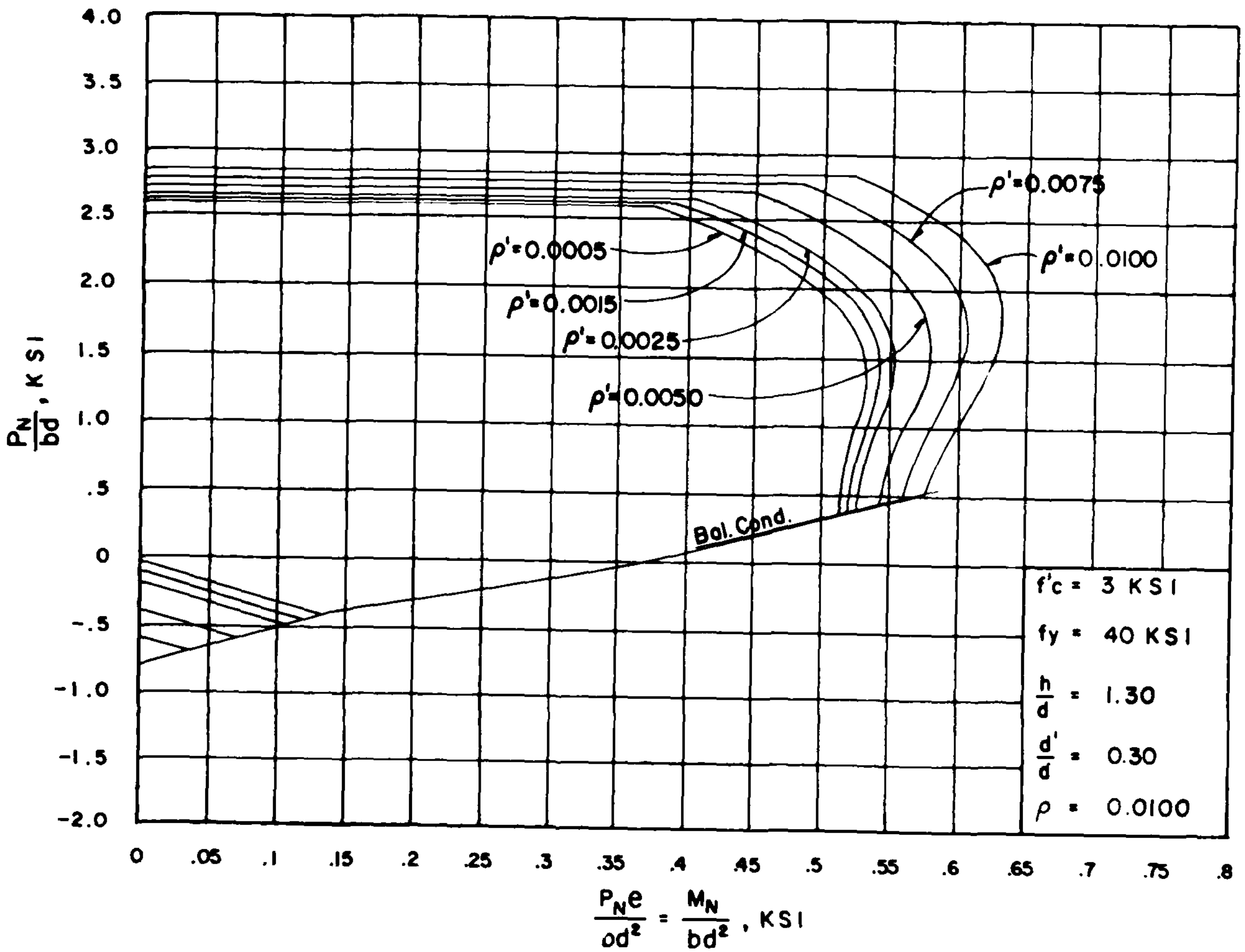


Figure 51. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0100)

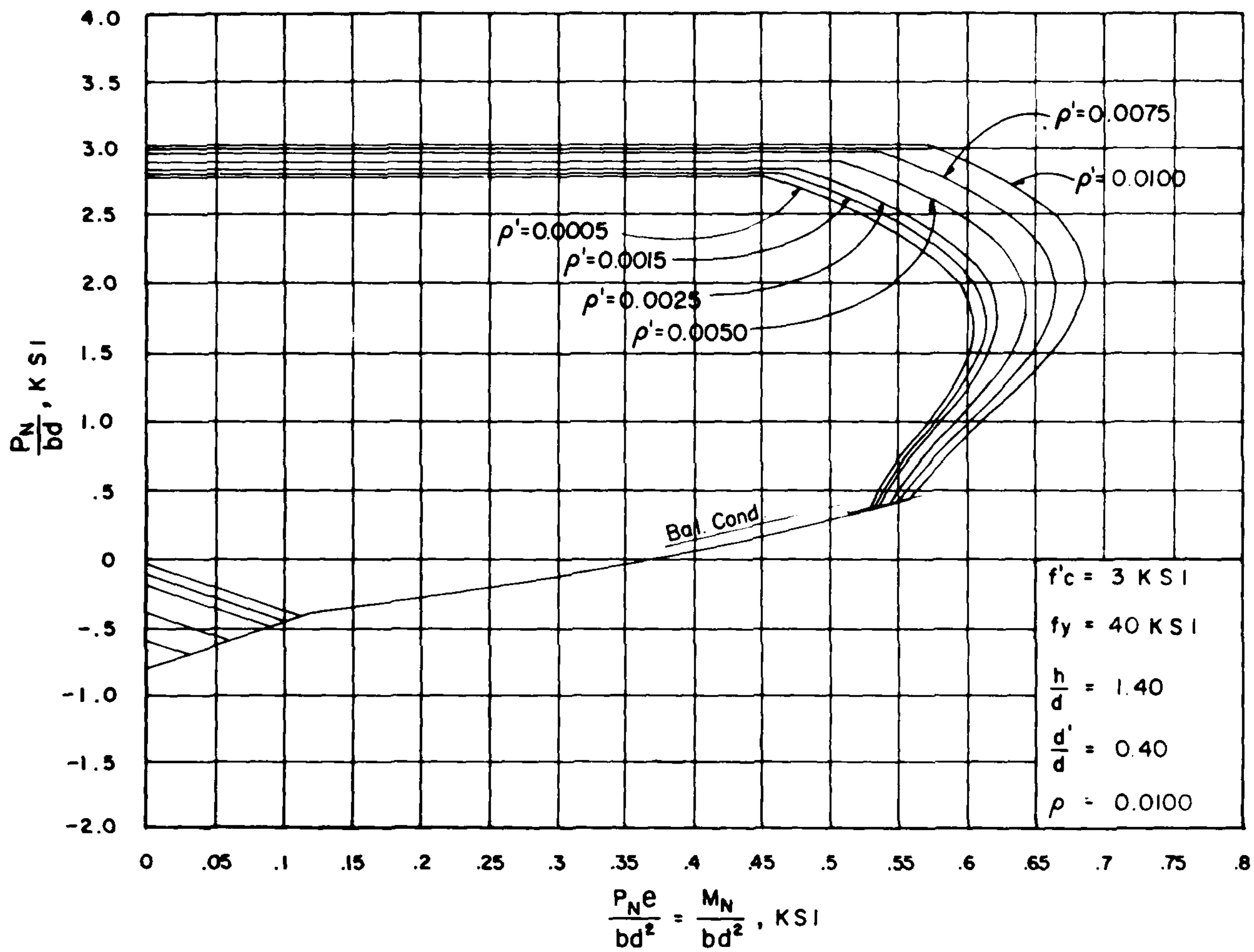


Figure 52. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0100)

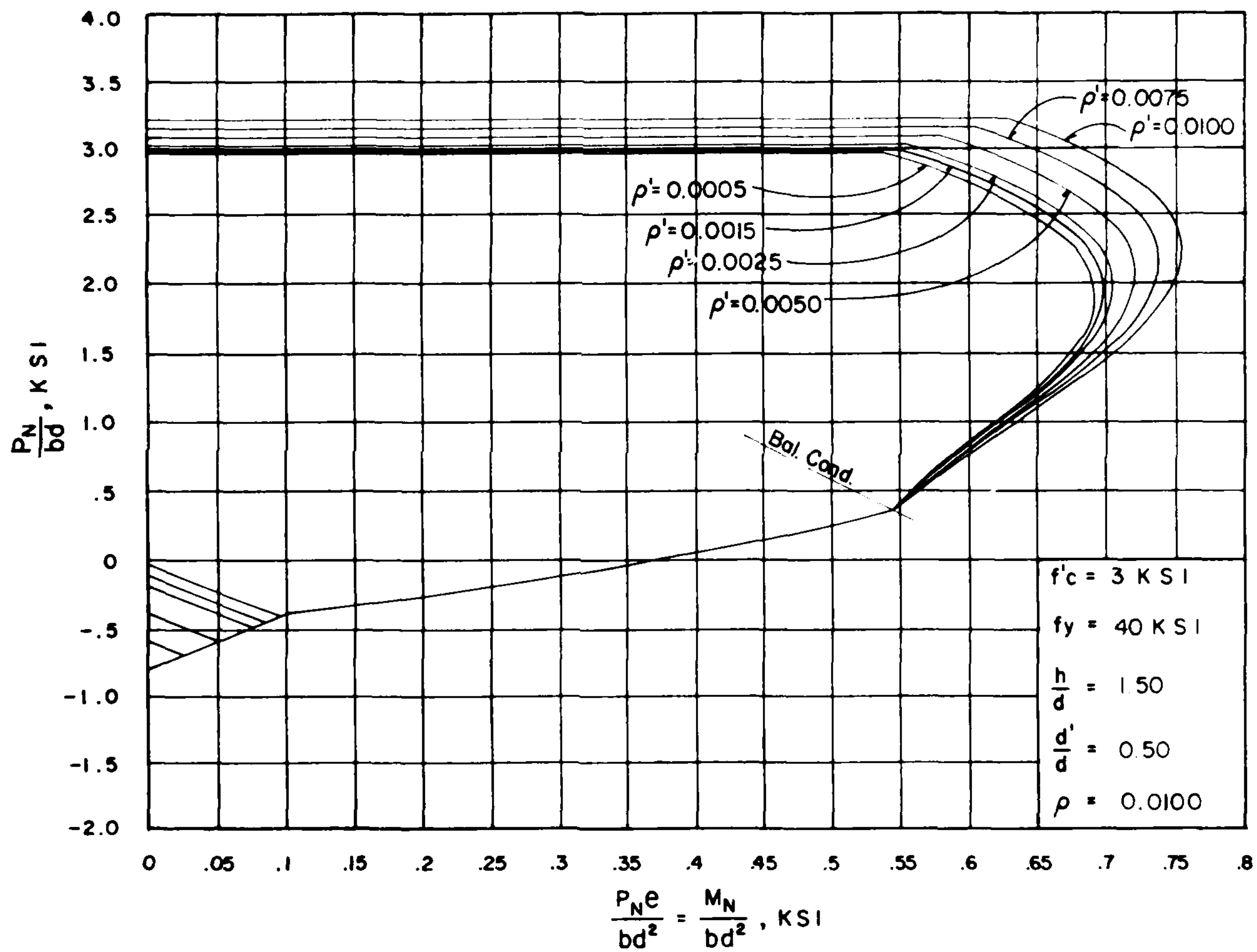


Figure 53. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0100)

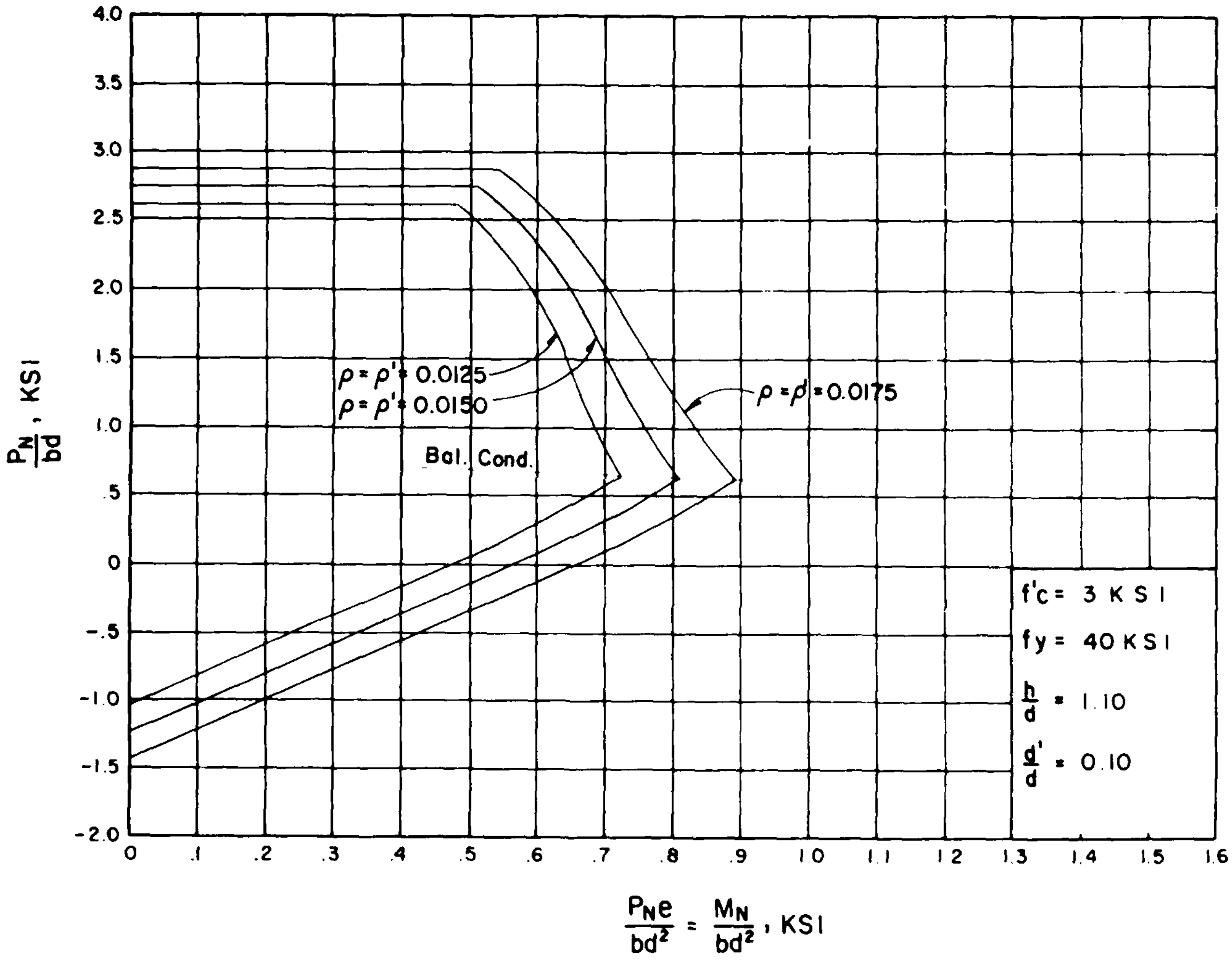


Figure 54. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.10, and d'/d = 0.10)

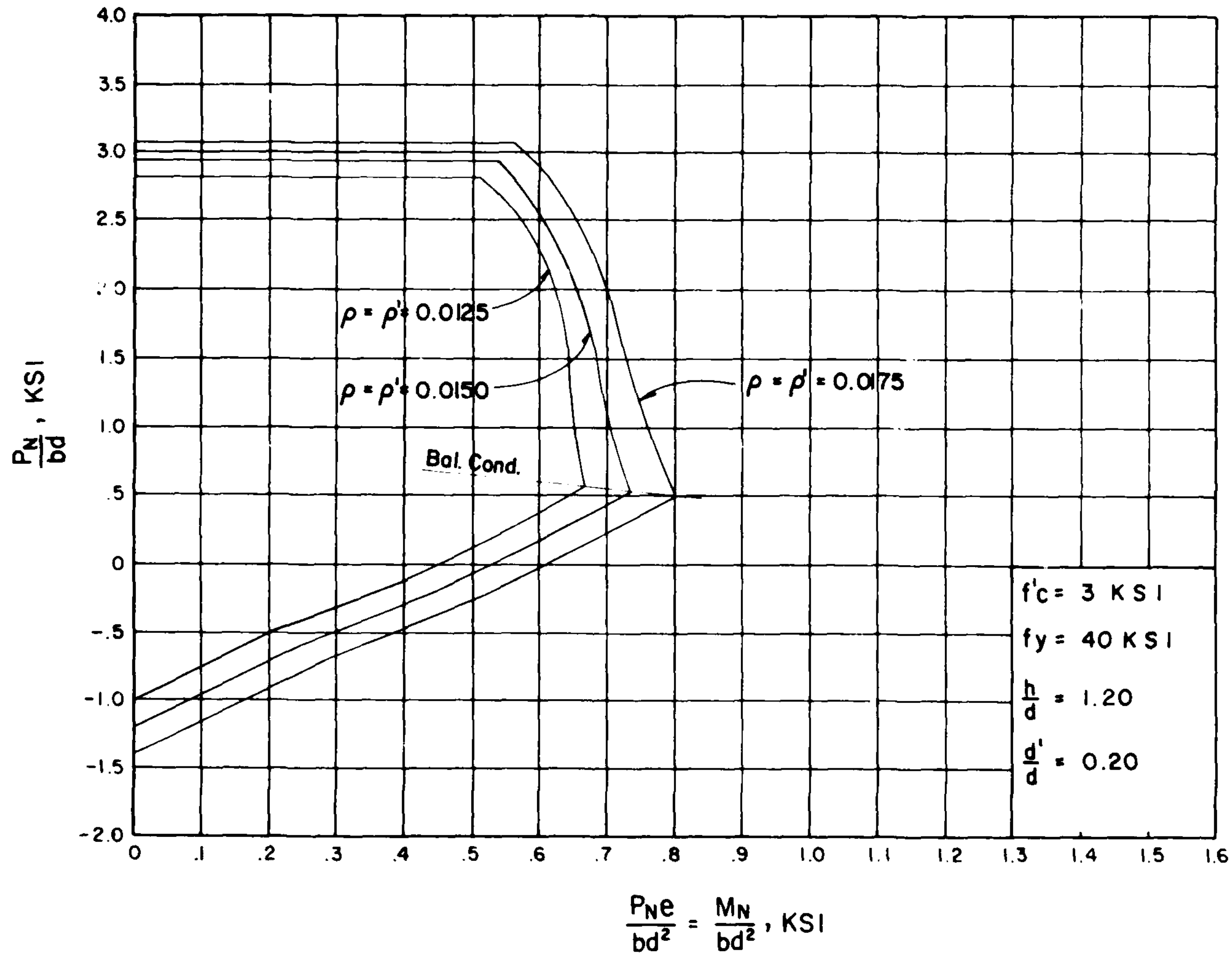


Figure 55. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.20, and d'/d = 0.20)

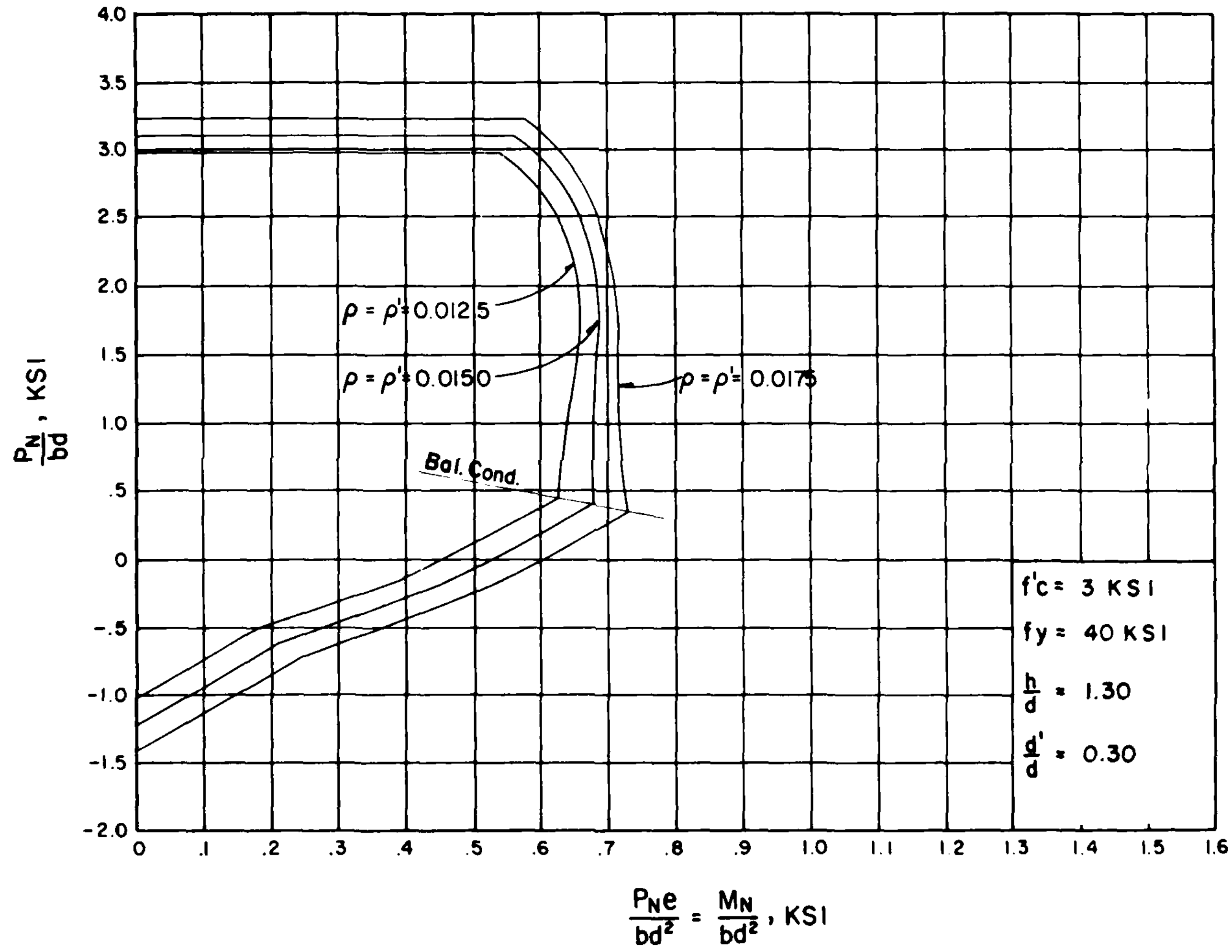


Figure 56. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.30, and d'/d = 0.30)

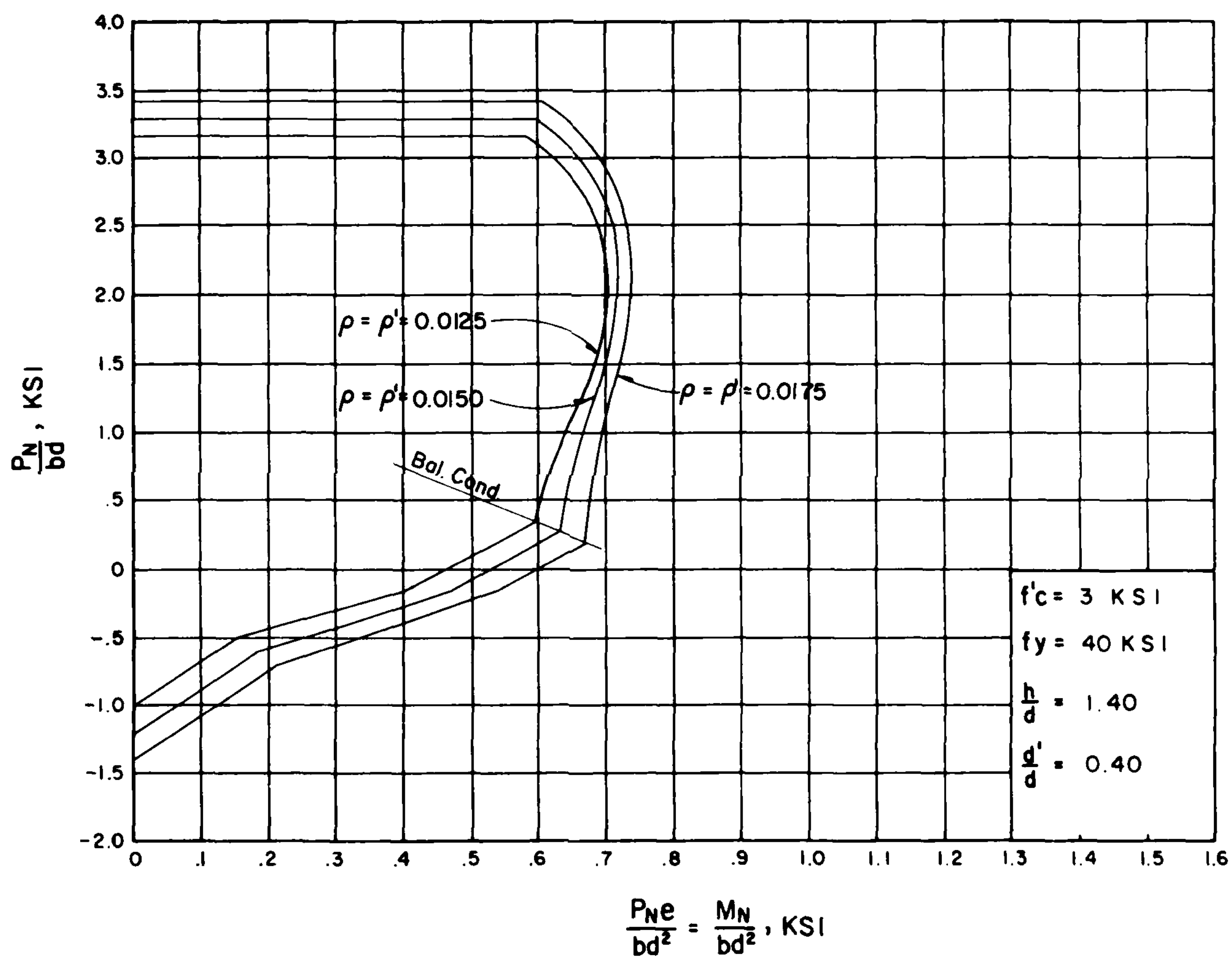


Figure 57. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.40, and d'/d = 0.40)

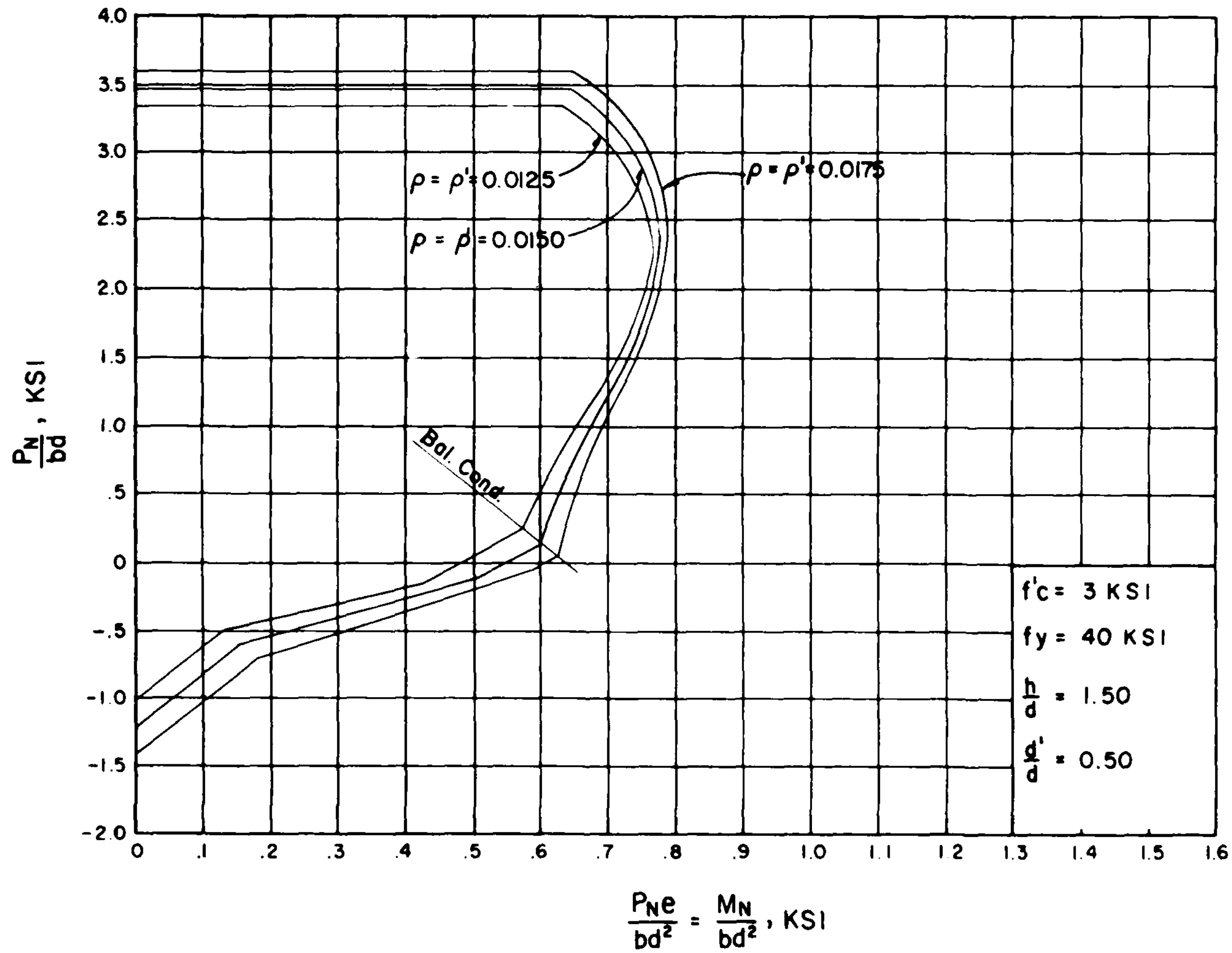


Figure 58. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 40 ksi, h/d = 1.50, and d'/d = 0.50)

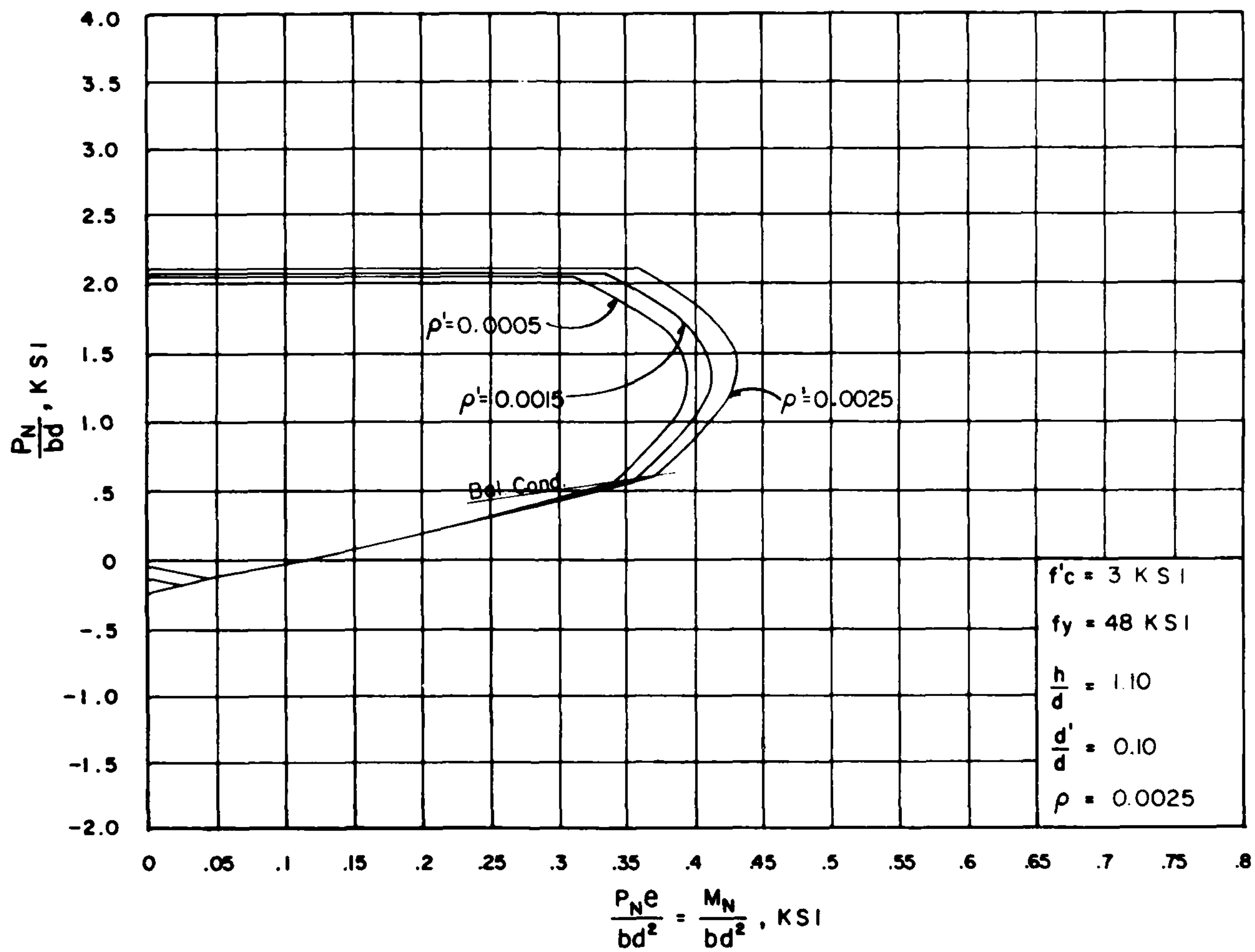


Figure 59. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0025)

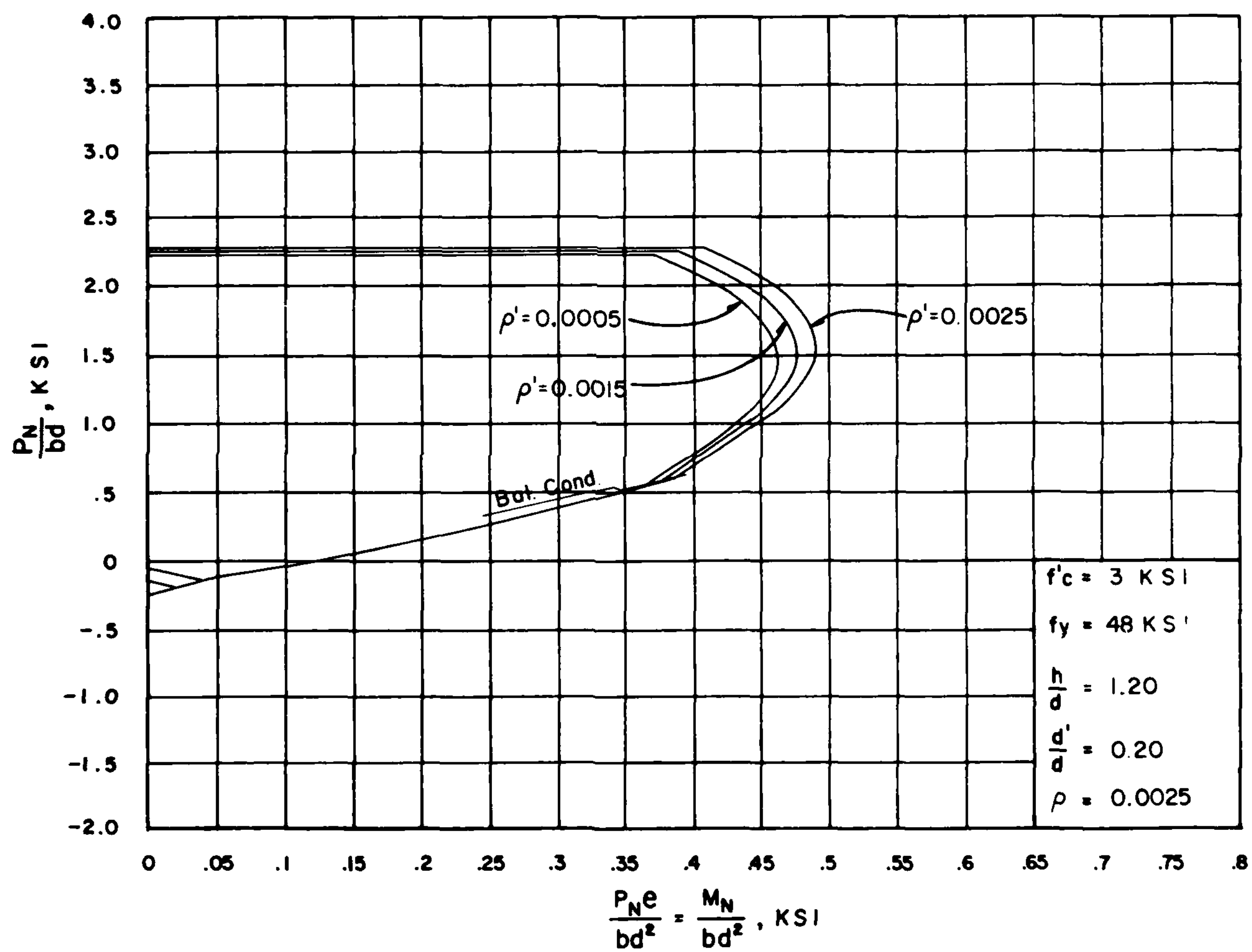


Figure 60. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0025)

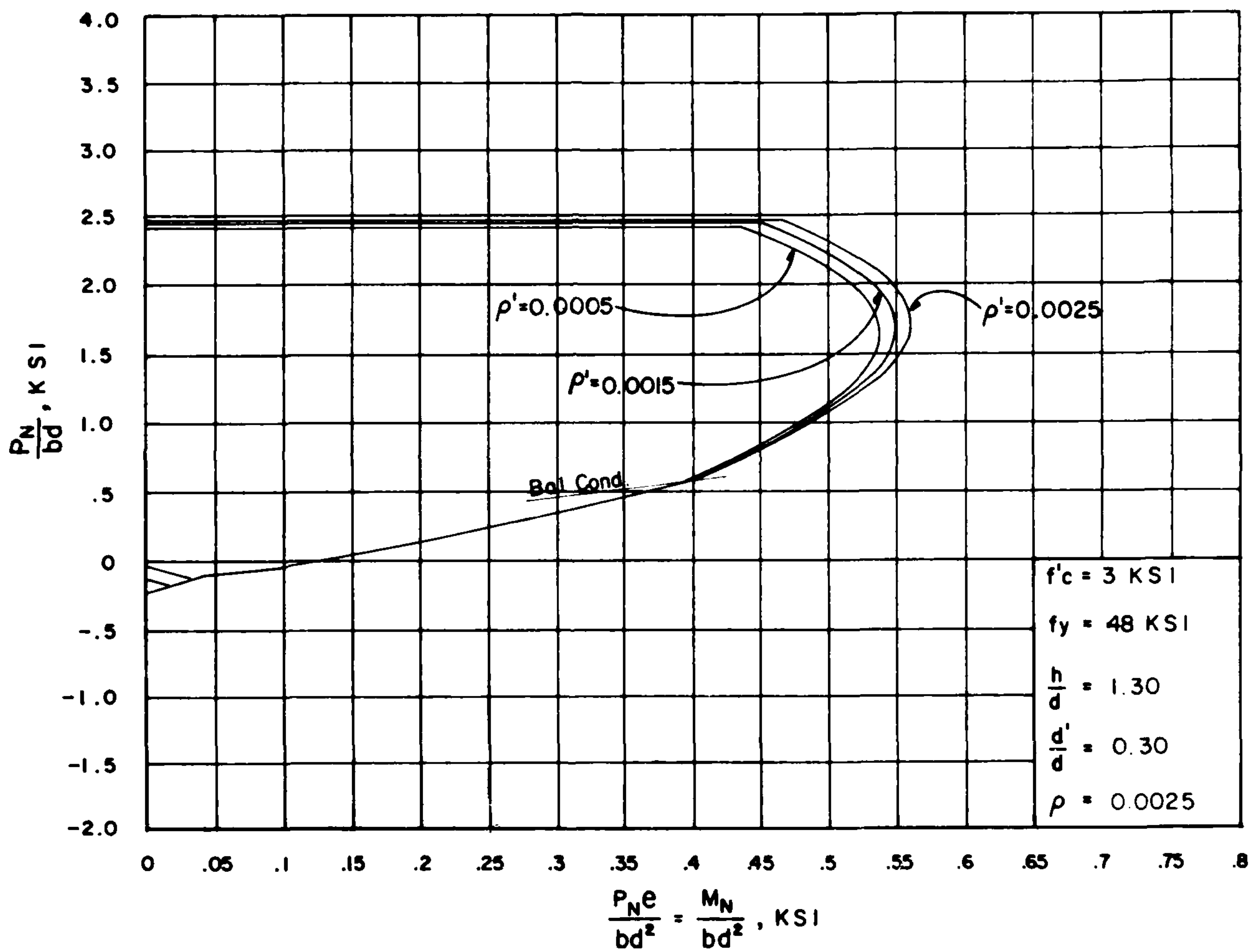


Figure 61. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0025)

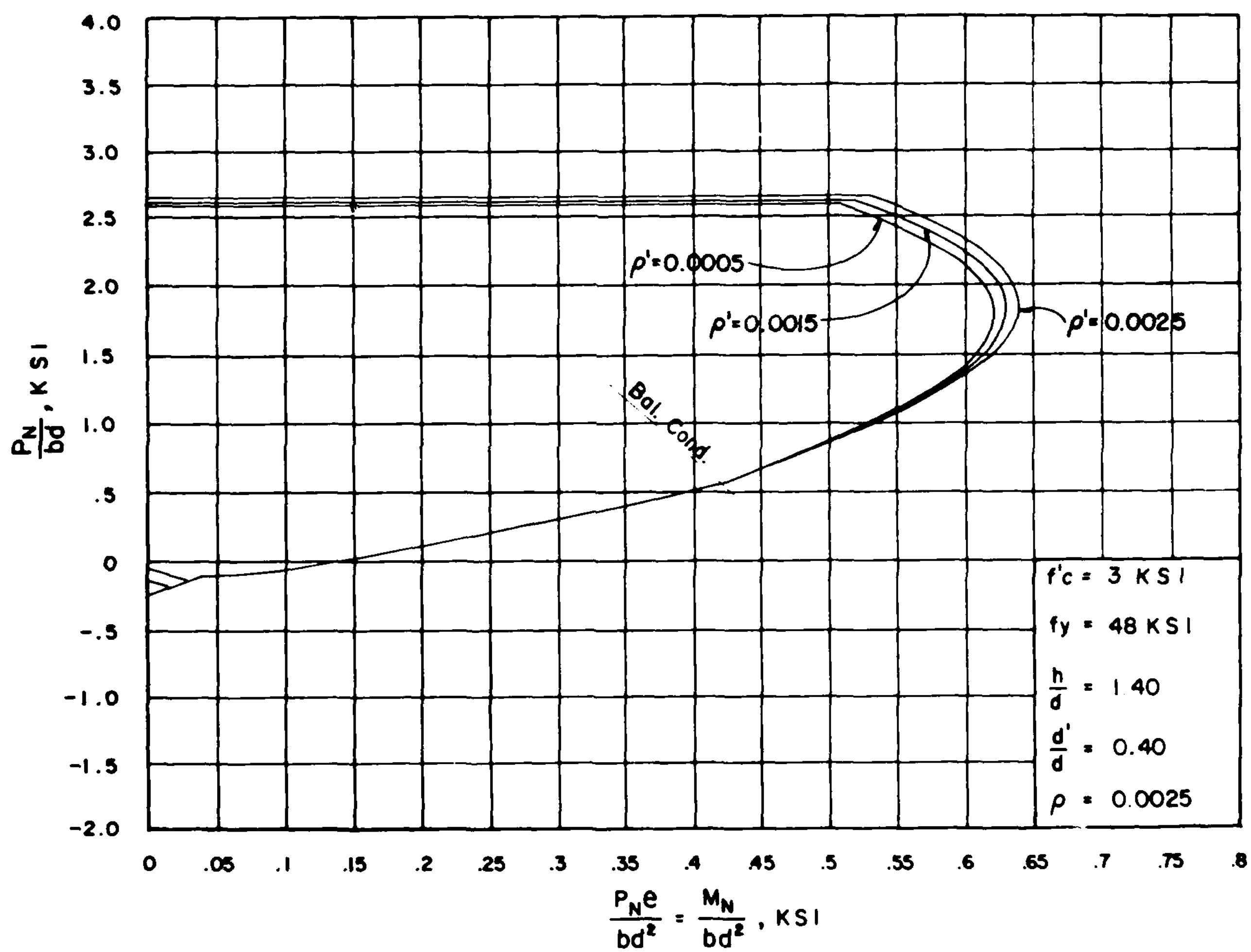


Figure 62. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0025)

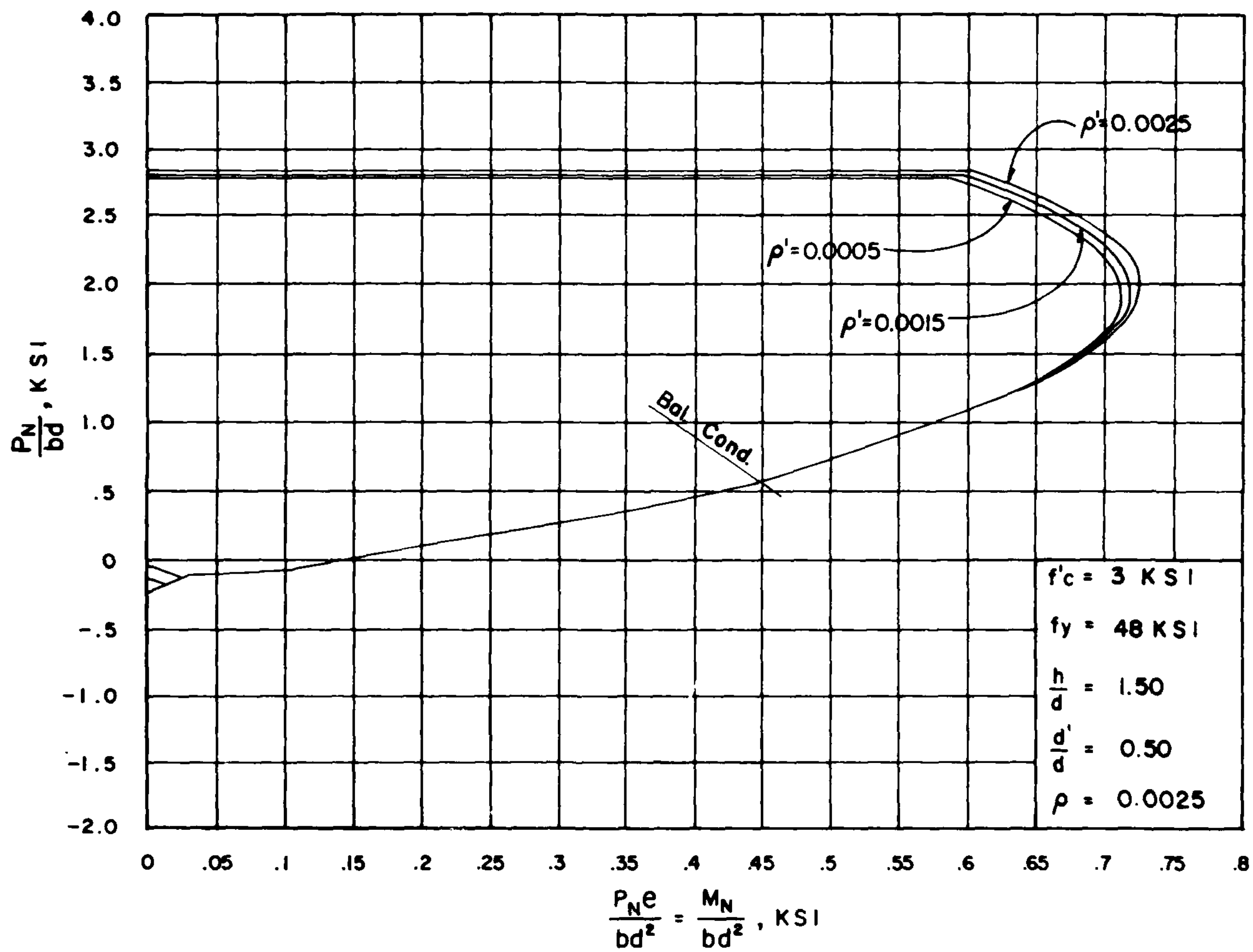


Figure 63. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0025)

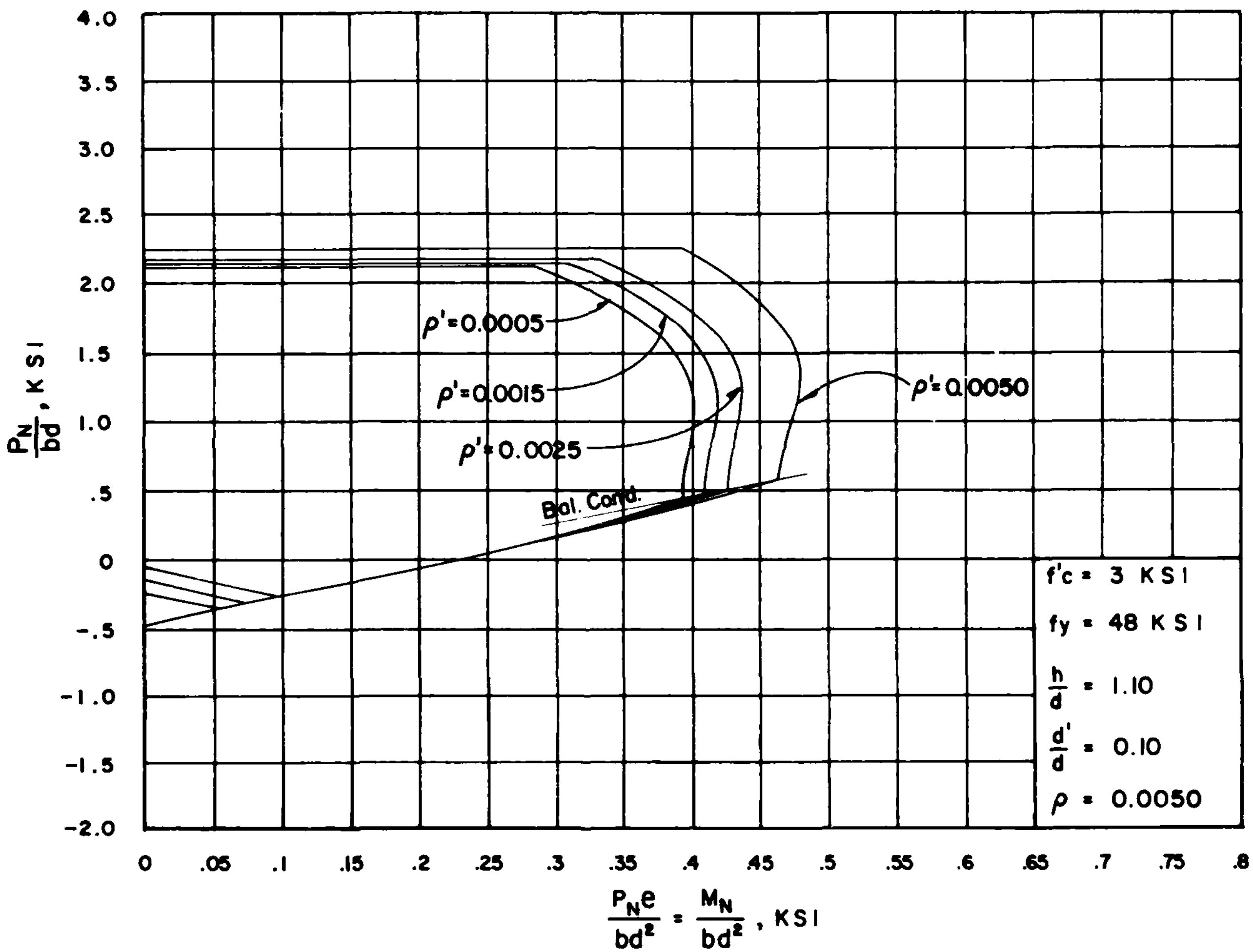


Figure 64. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0050)

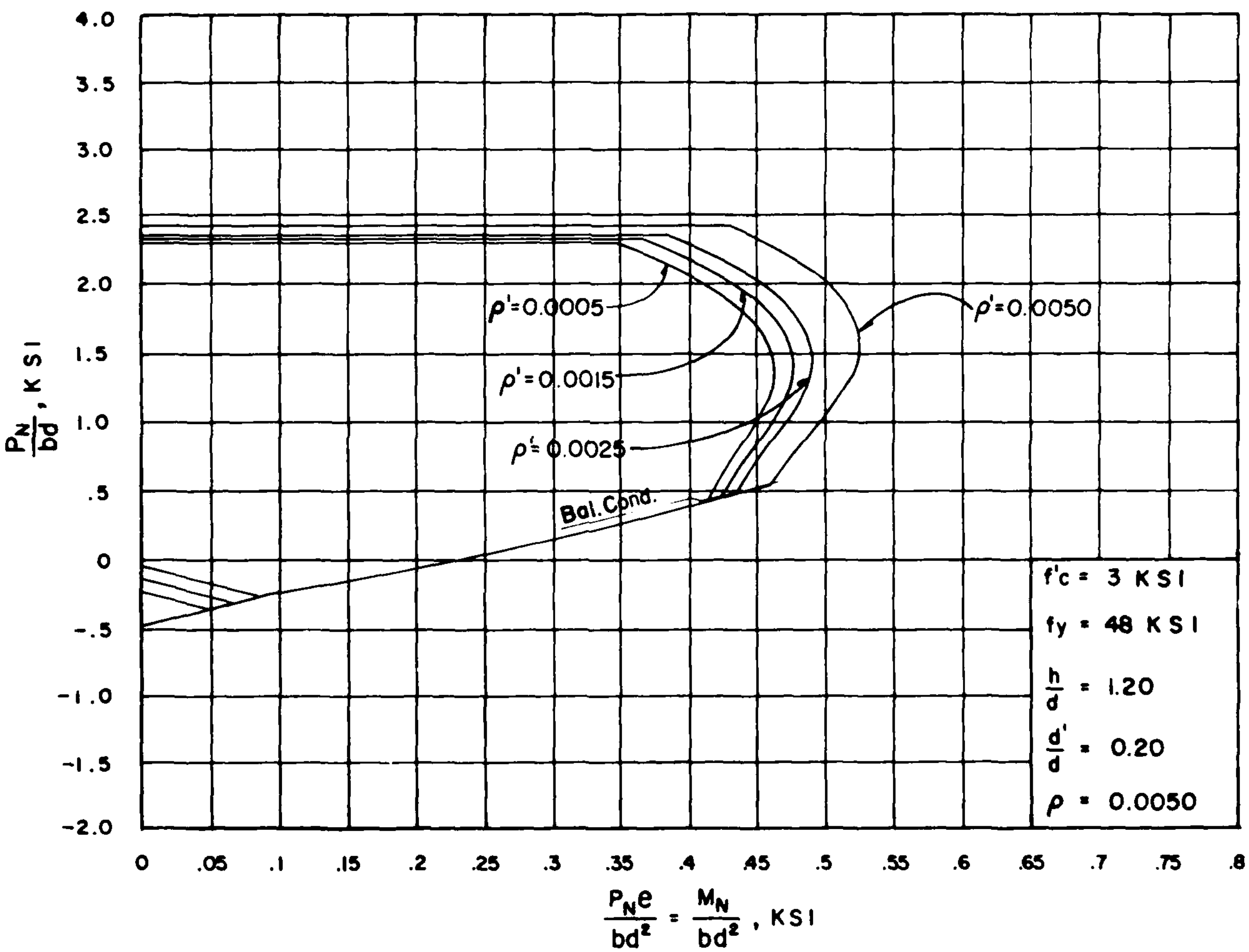


Figure 65. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0050)

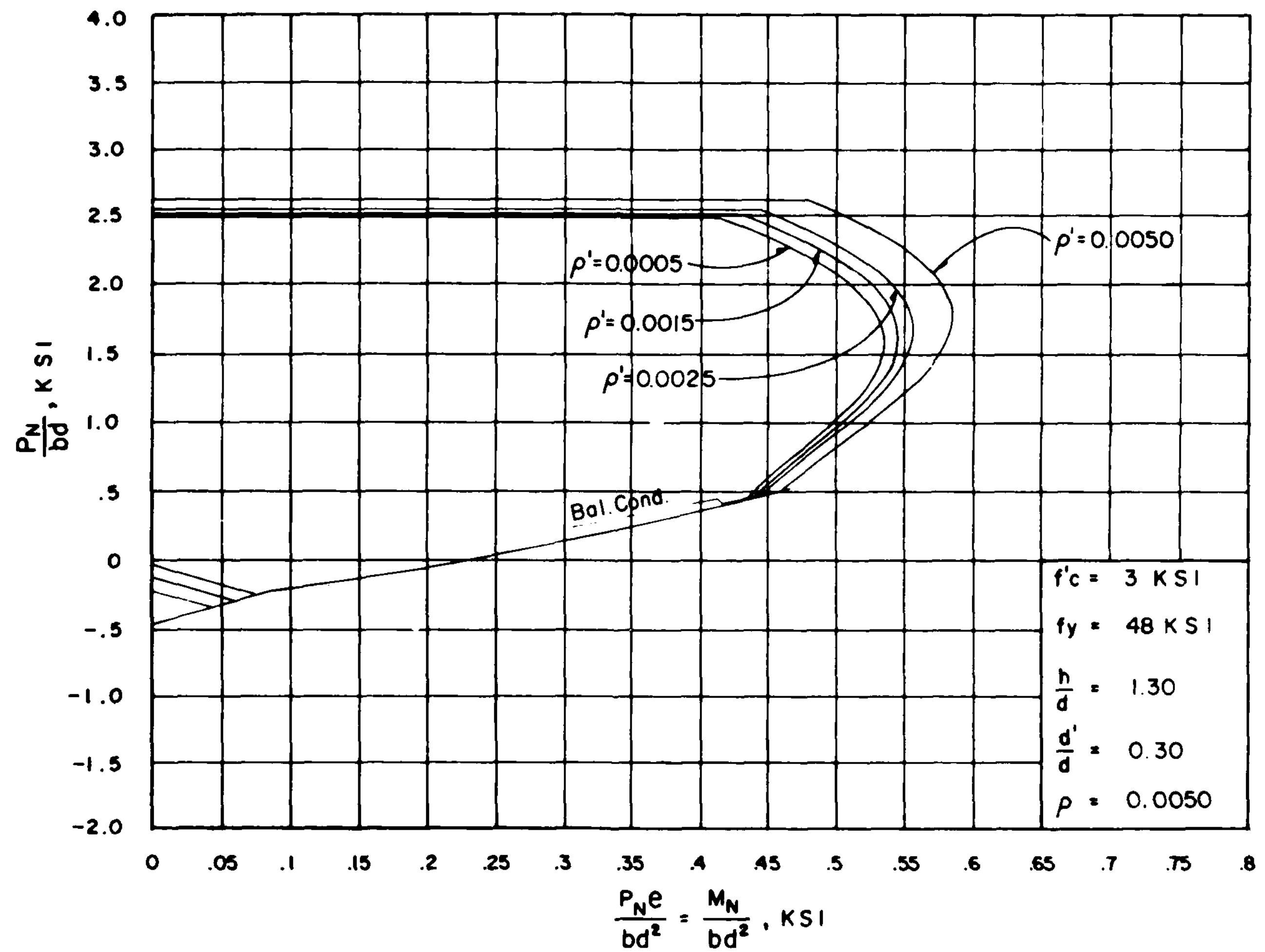


Figure 66. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0050)

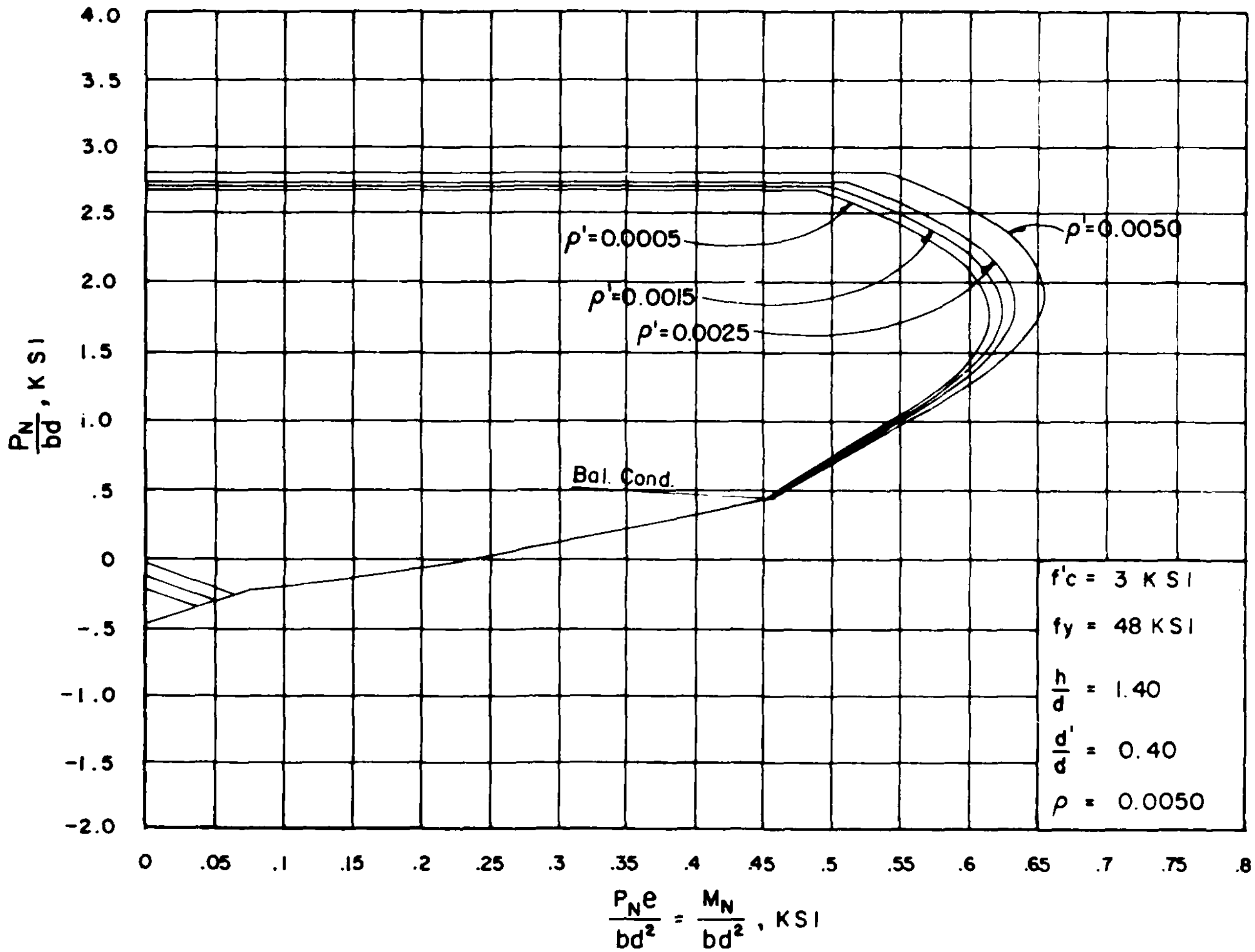


Figure 67. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0050)

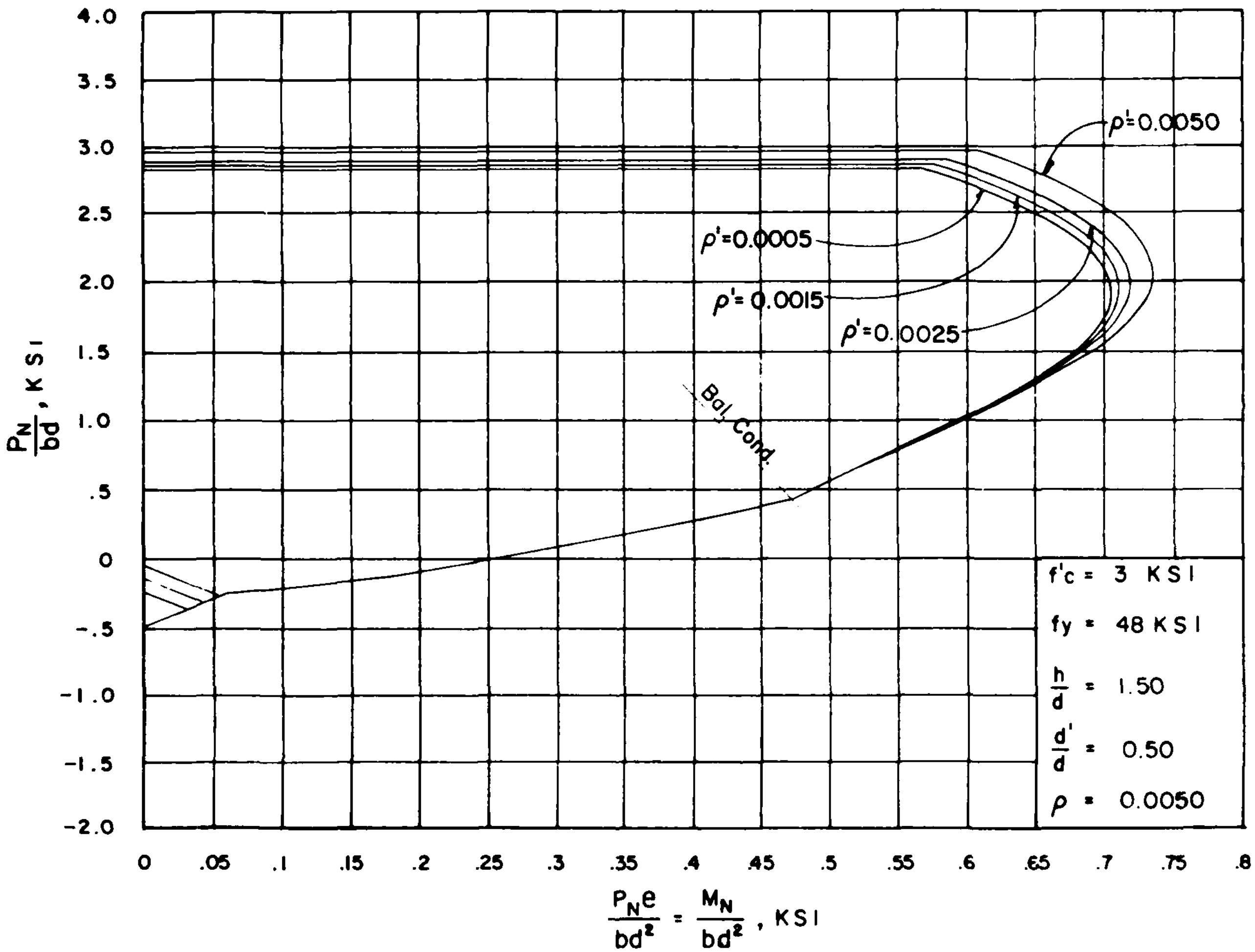
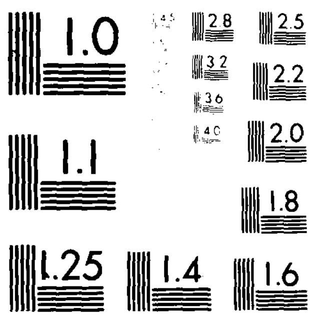


Figure 68. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0050)

AD-A111 648 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/13
STRENGTH DESIGN OF REINFORCED CONCRETE HYDRAULIC STRUCTURES. RE--ETC(U)
DEC 81 T C LIU, S GLEASON
UNCLASSIFIED WES/TR/SL-80-4 NL

2 OF 3
AD
A111648



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

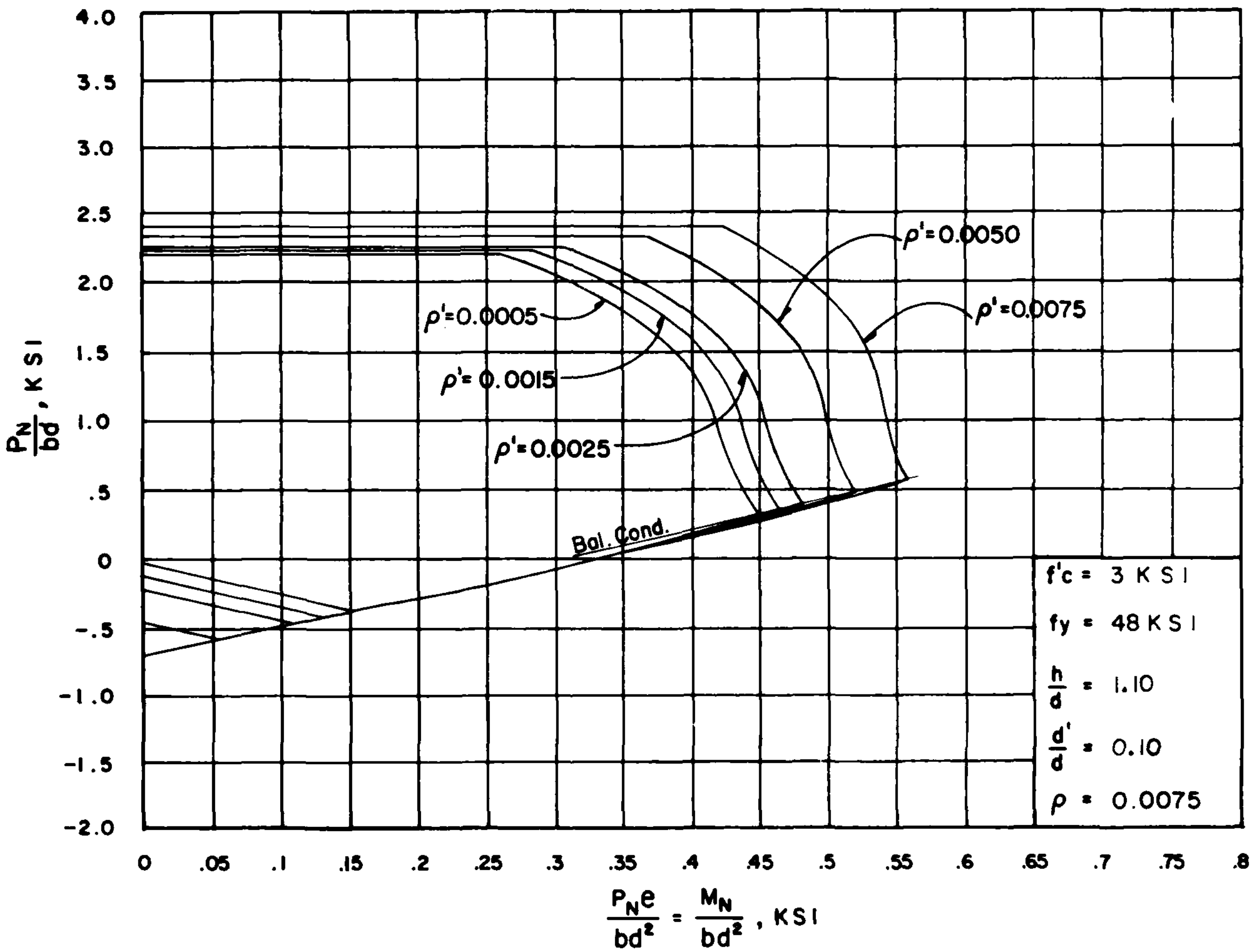


Figure 69. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0075)

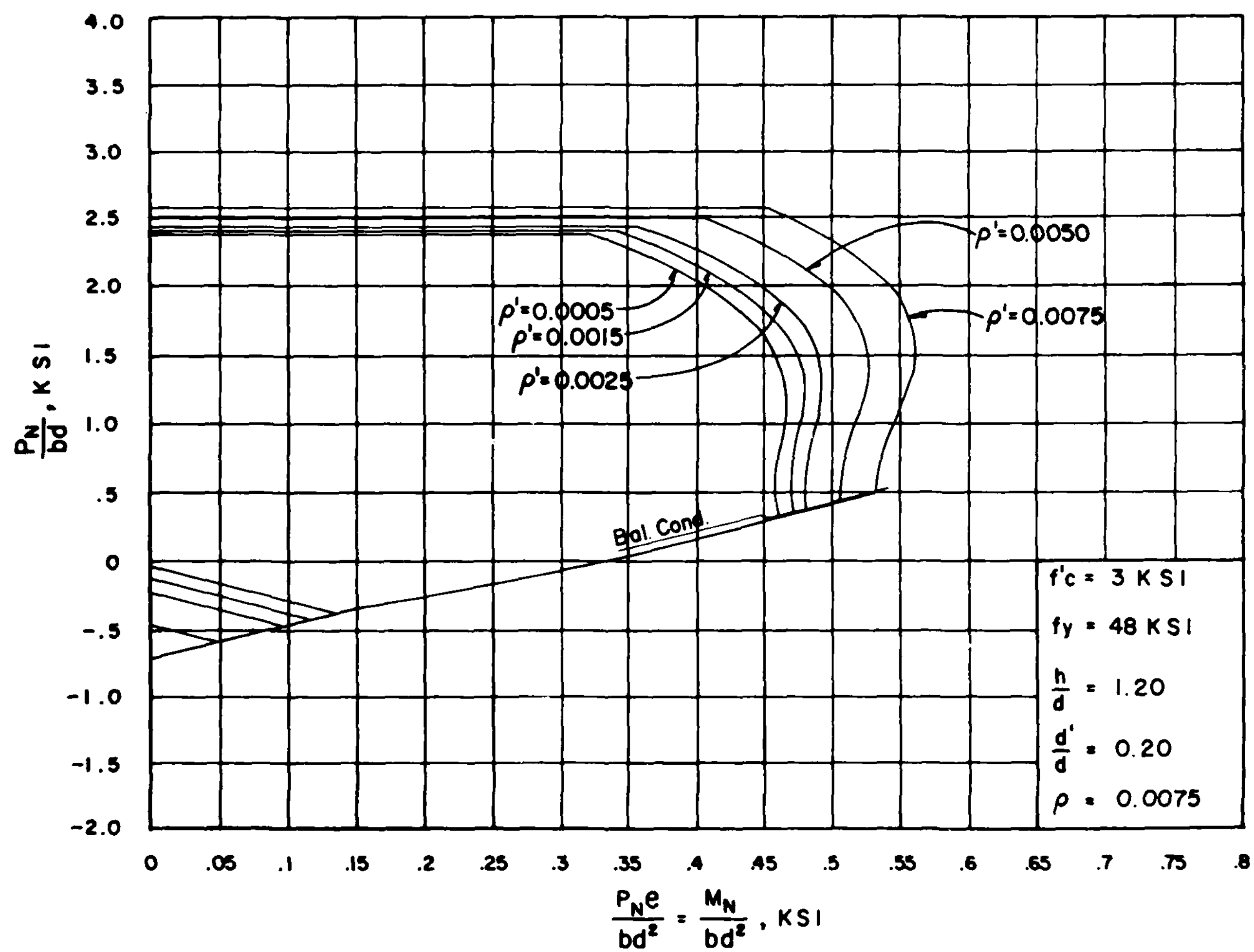


Figure 70. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0075)

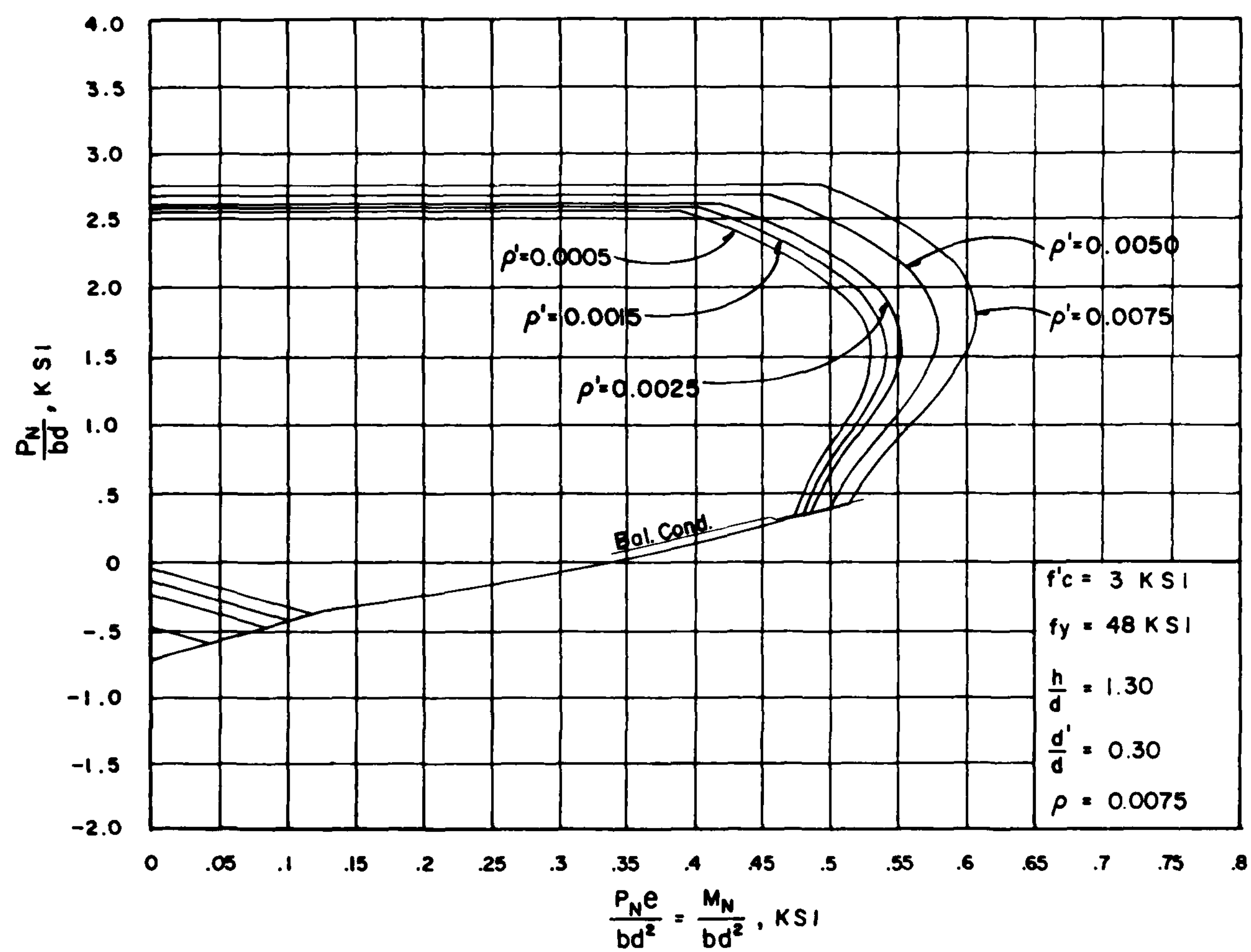


Figure 71. Loa ment strength interaction diagram for double reinforced members (f'_c = 3 ' f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0075)

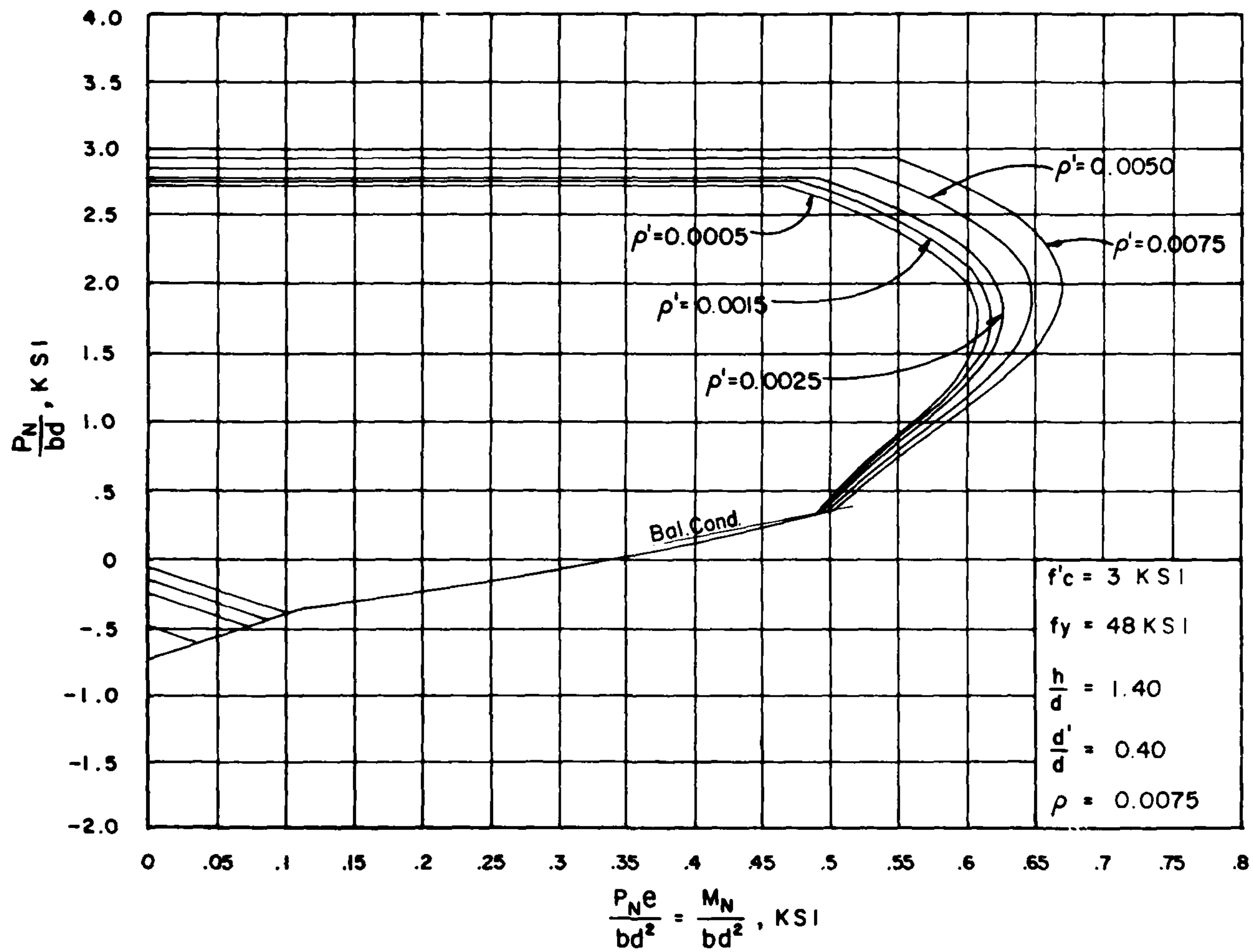


Figure 72. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0075)

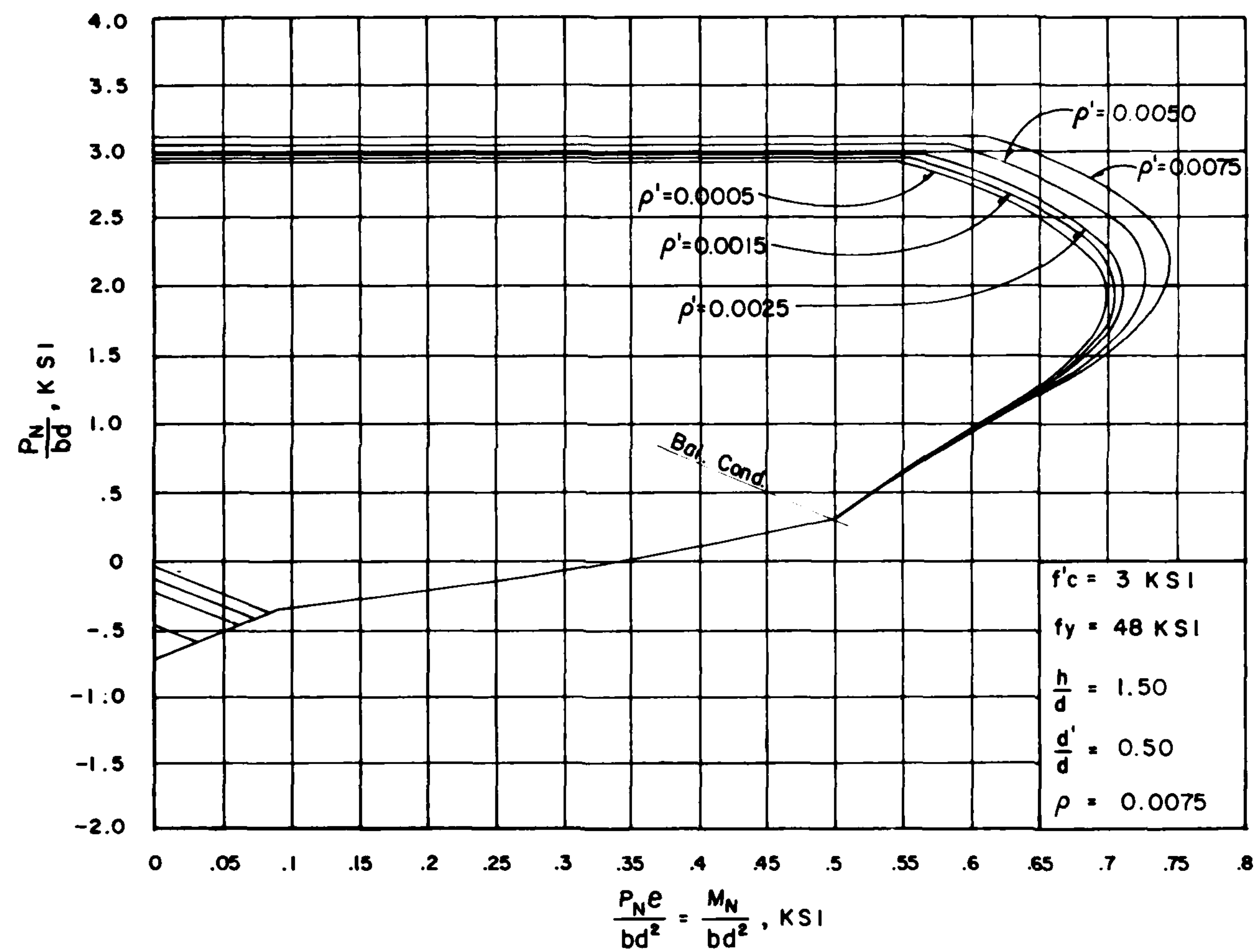


Figure 73. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0075)

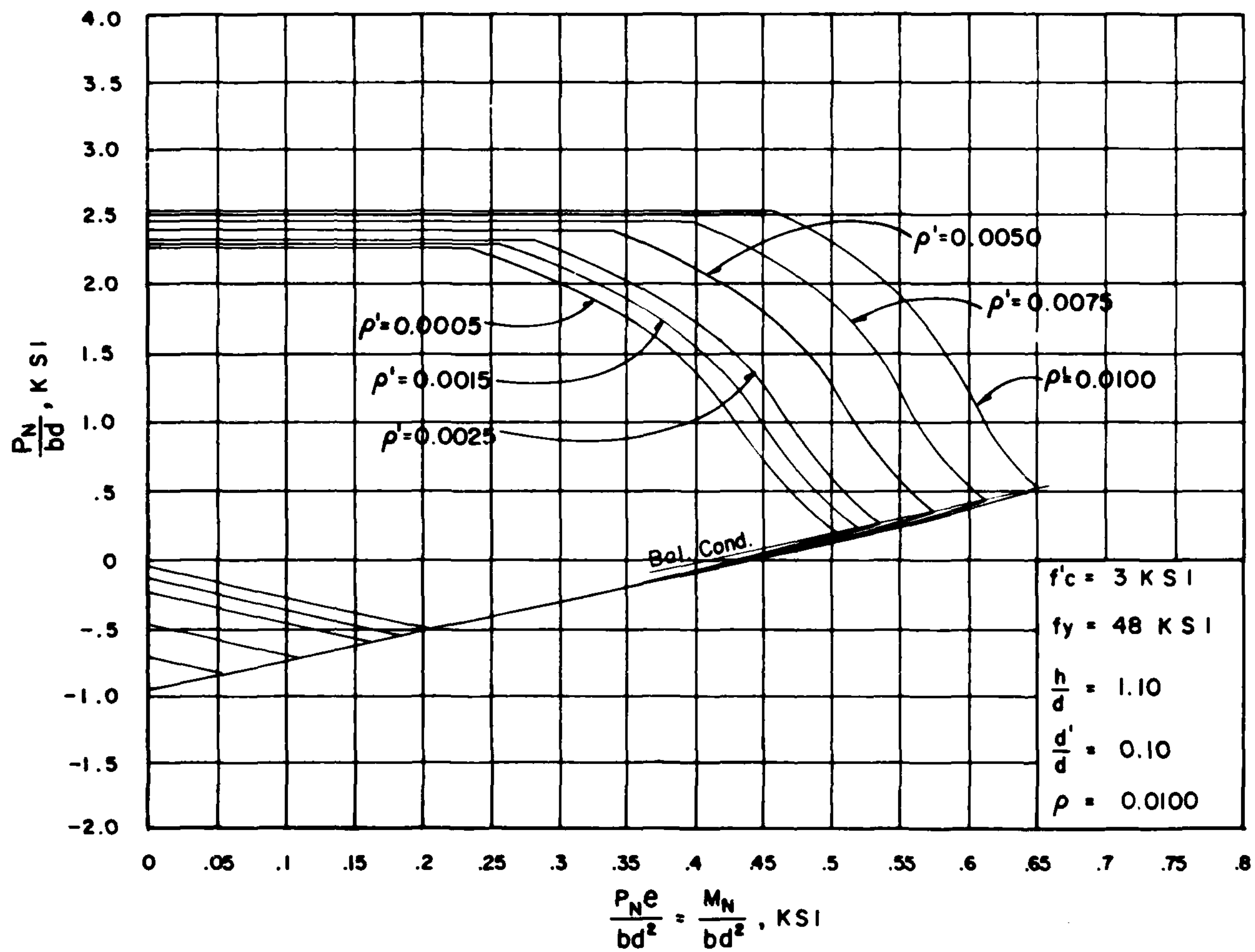


Figure 74. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0100)

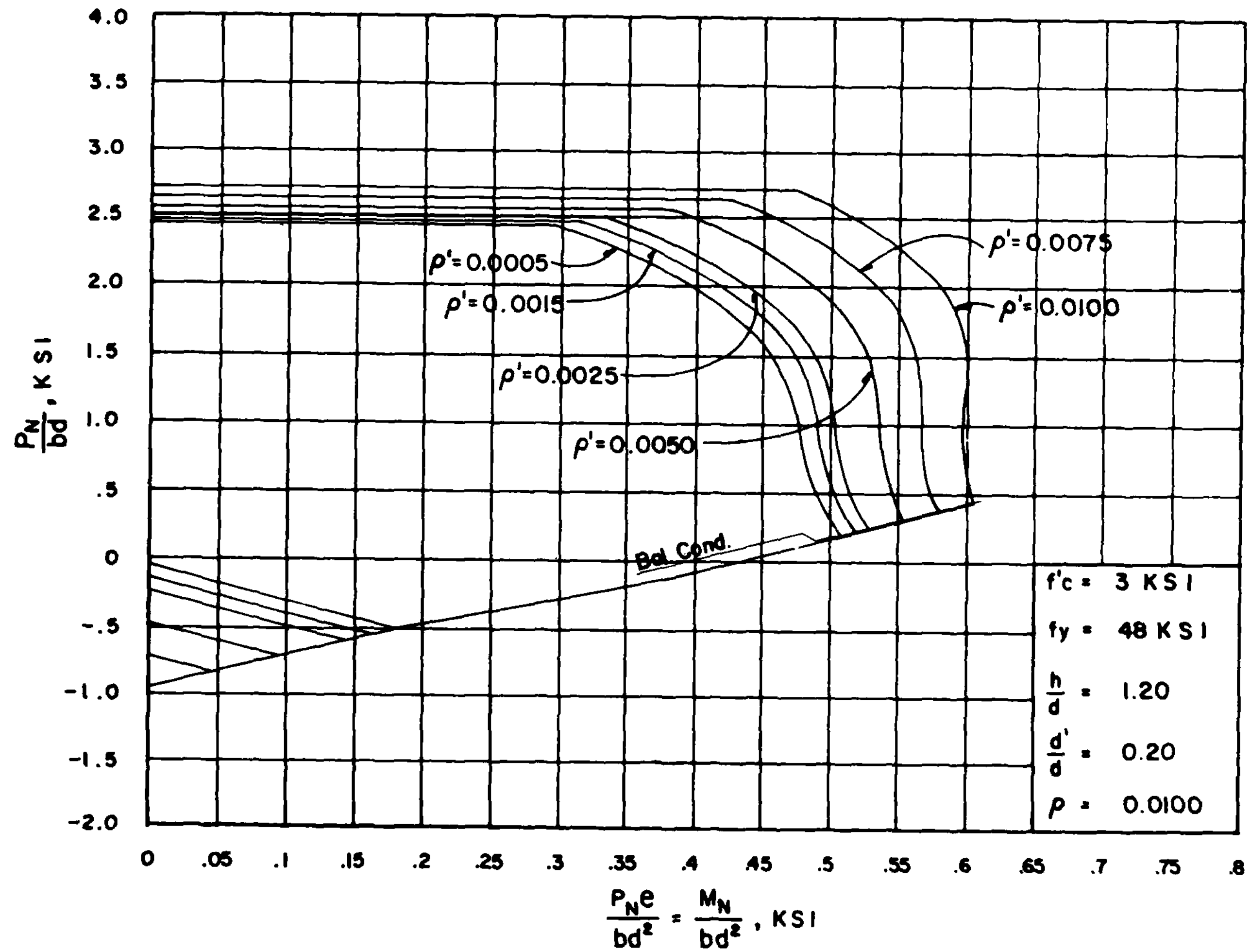


Figure 75. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0100)

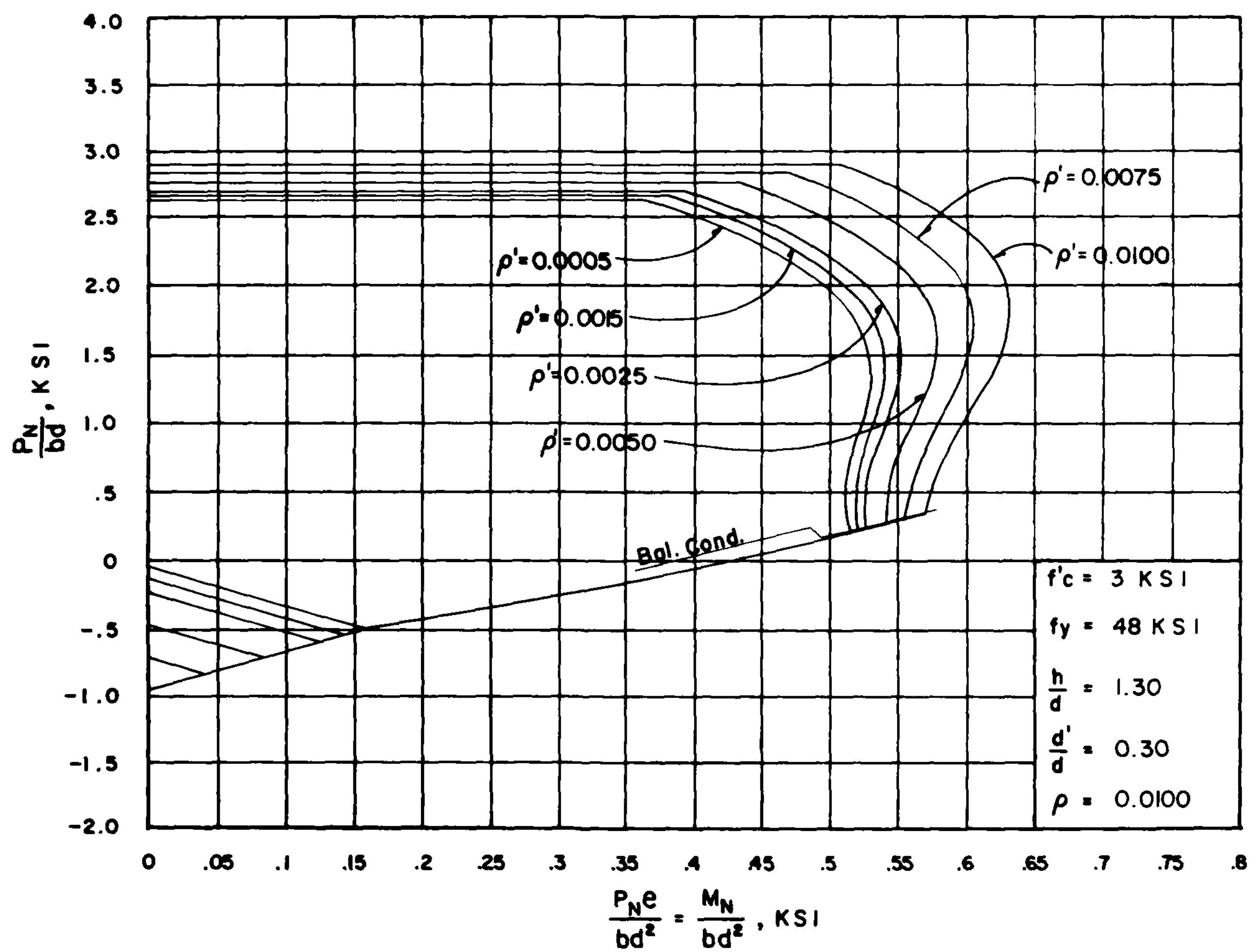


Figure 76. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0100)

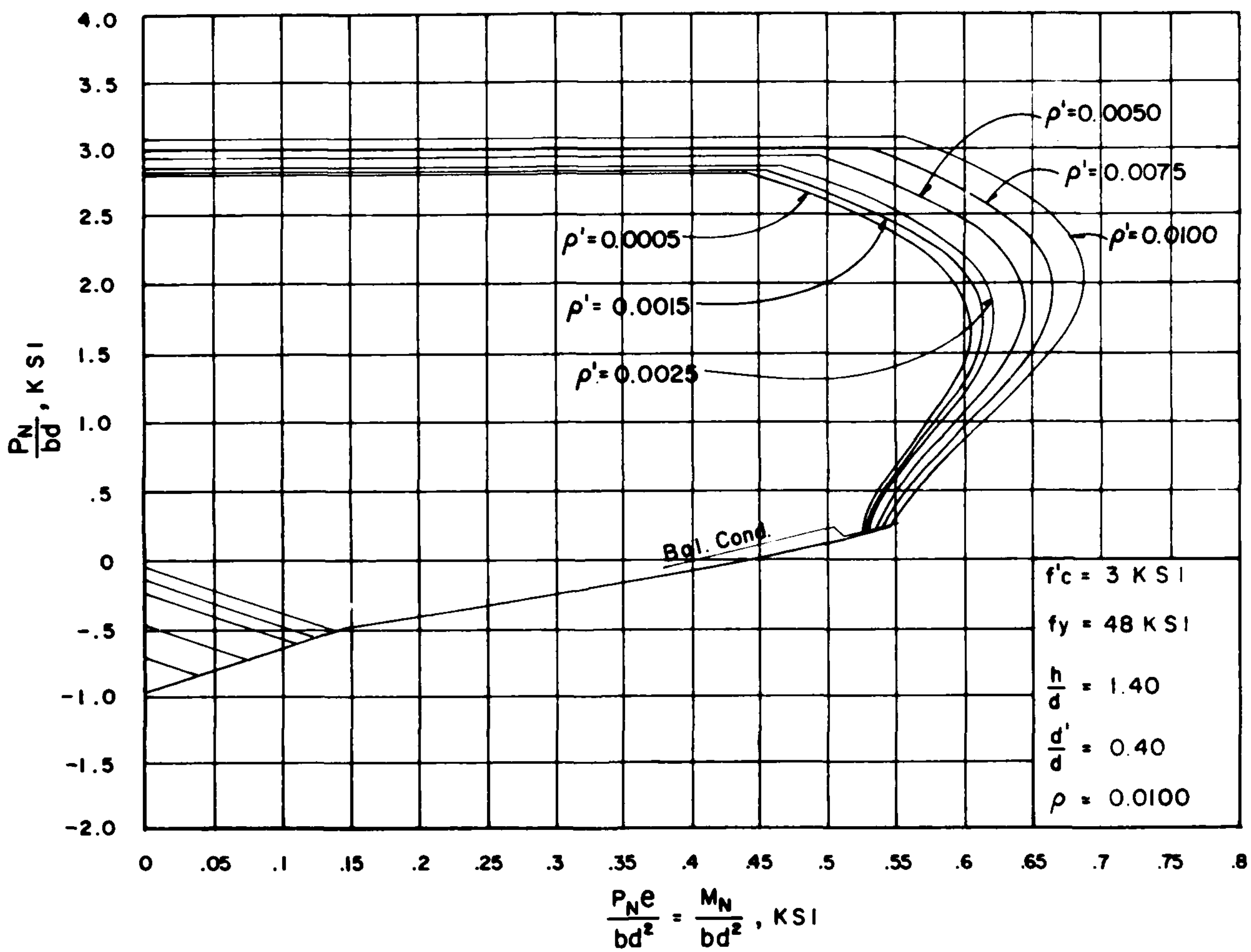


Figure 77. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0100)

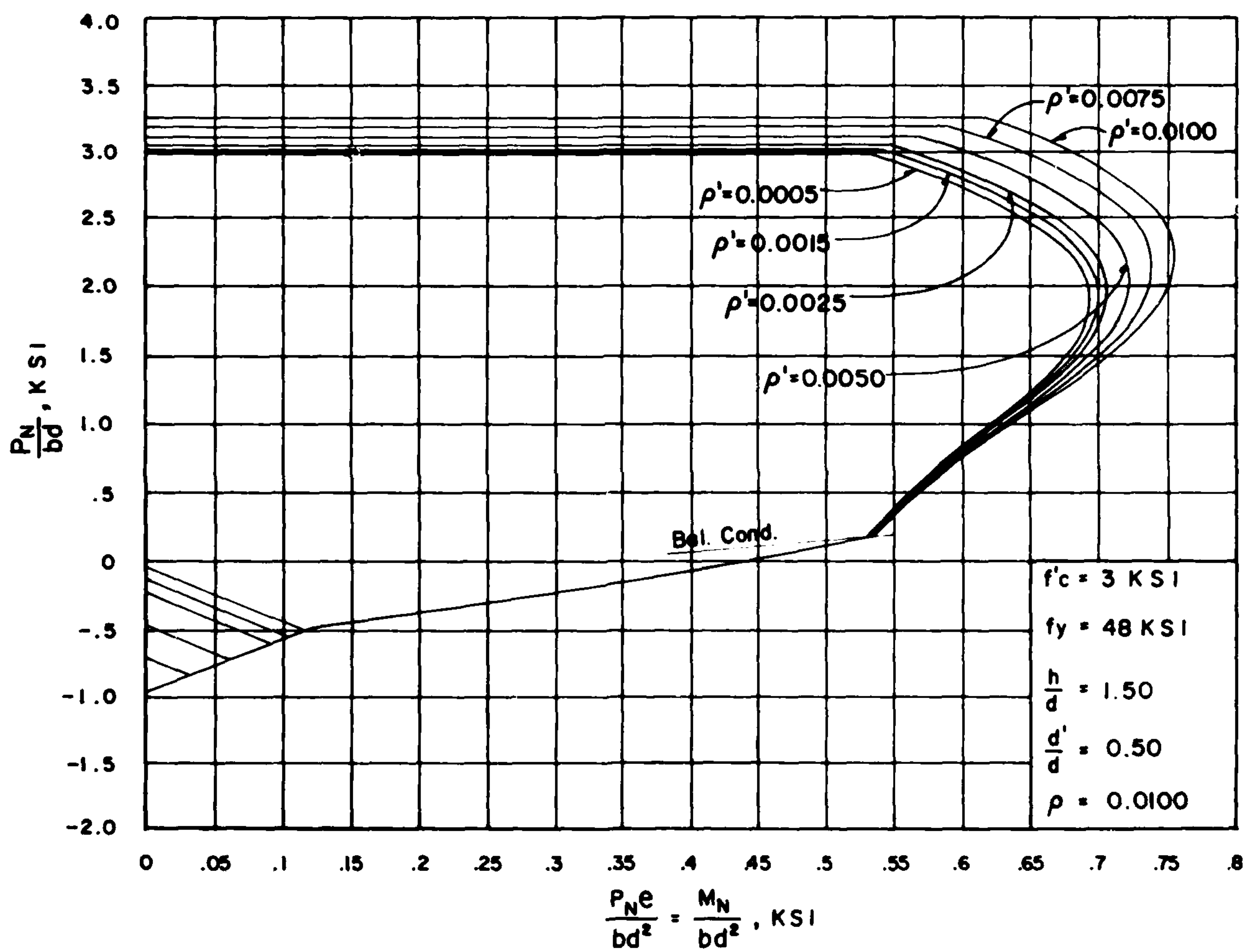


Figure 78. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0100)

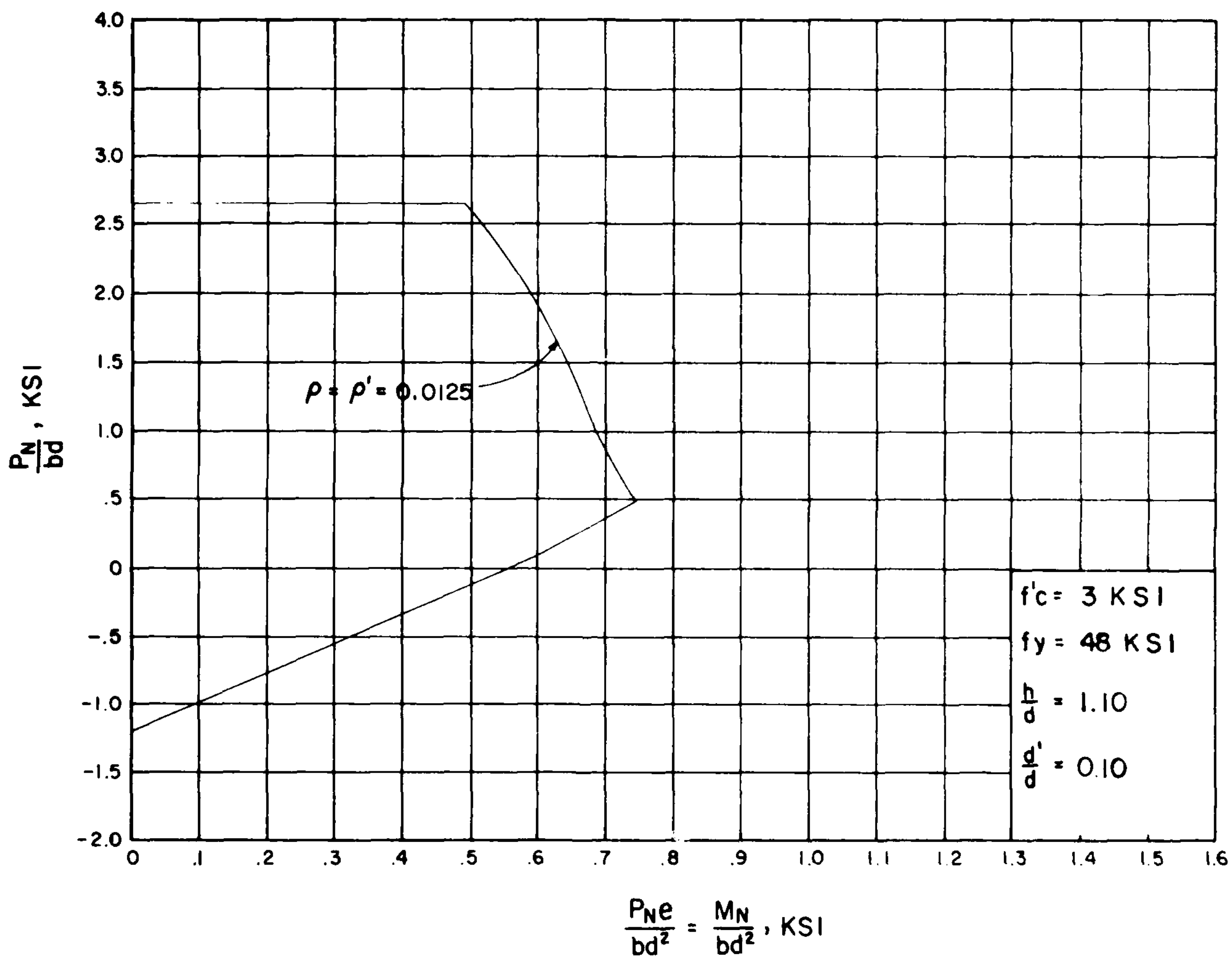


Figure 79. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.10, and d'/d = 0.10)

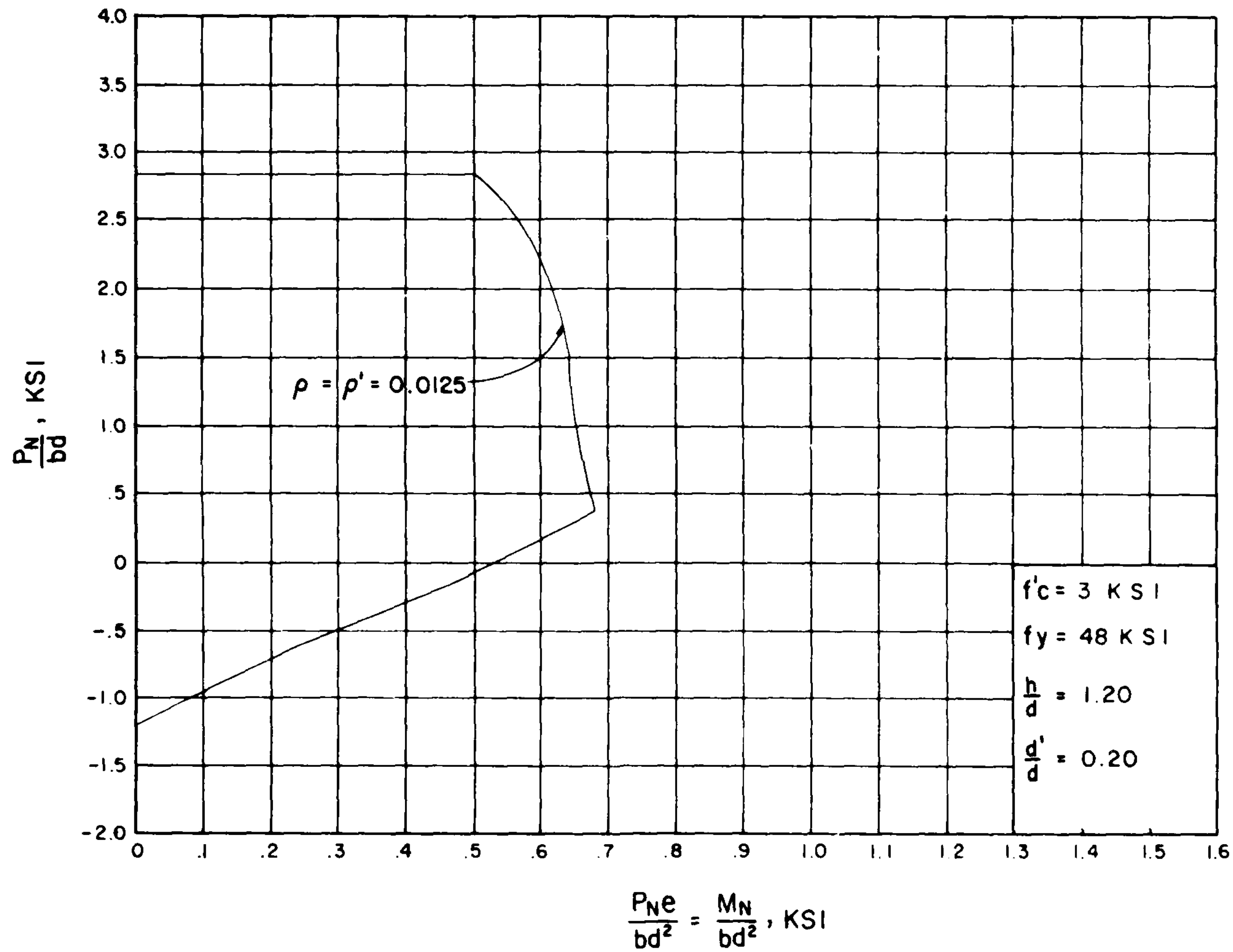


Figure 80. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.20, and d'/d = 0.20)

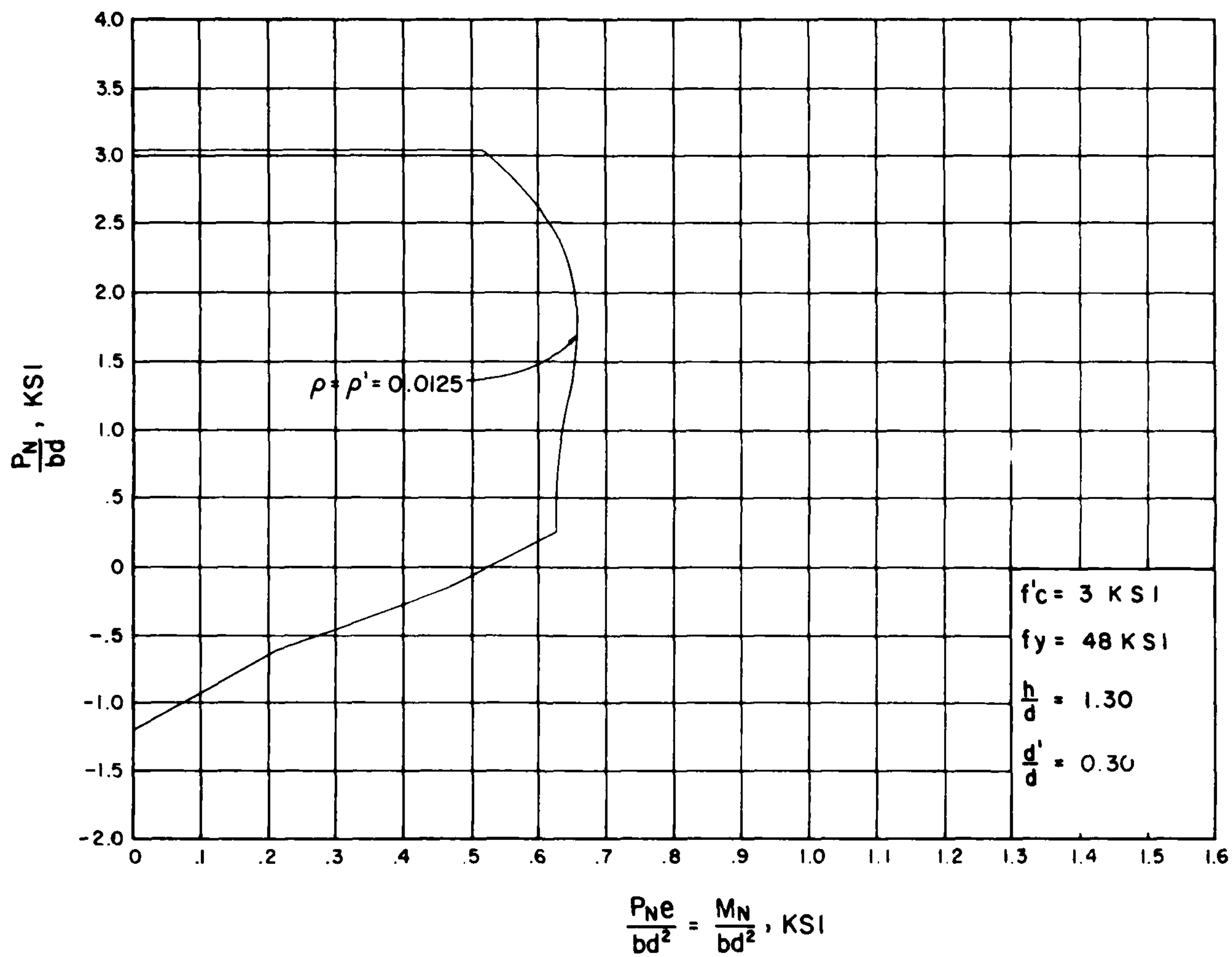


Figure 81. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.30, and d'/d = 0.30)

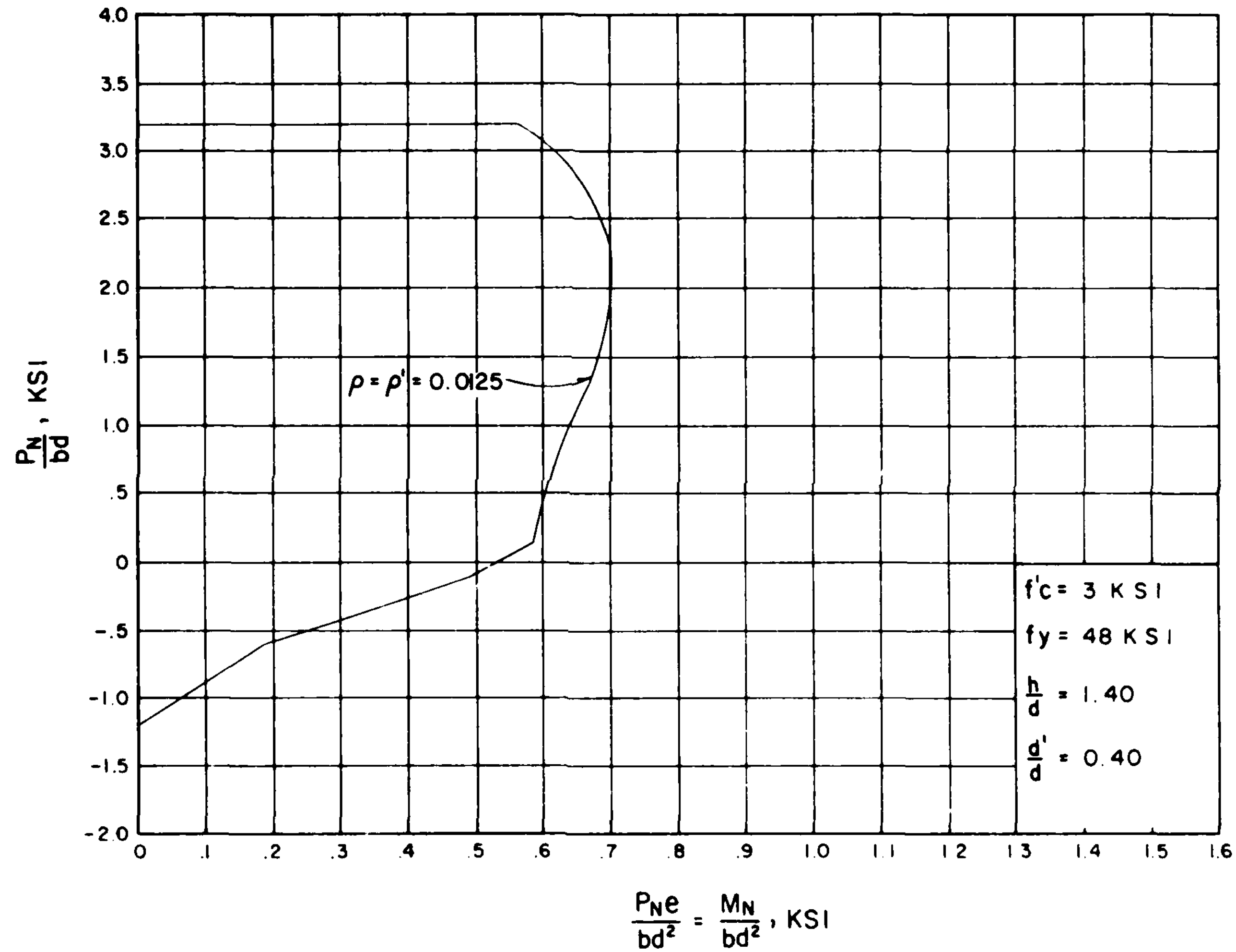


Figure 82. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.40, and d'/d = 0.40)

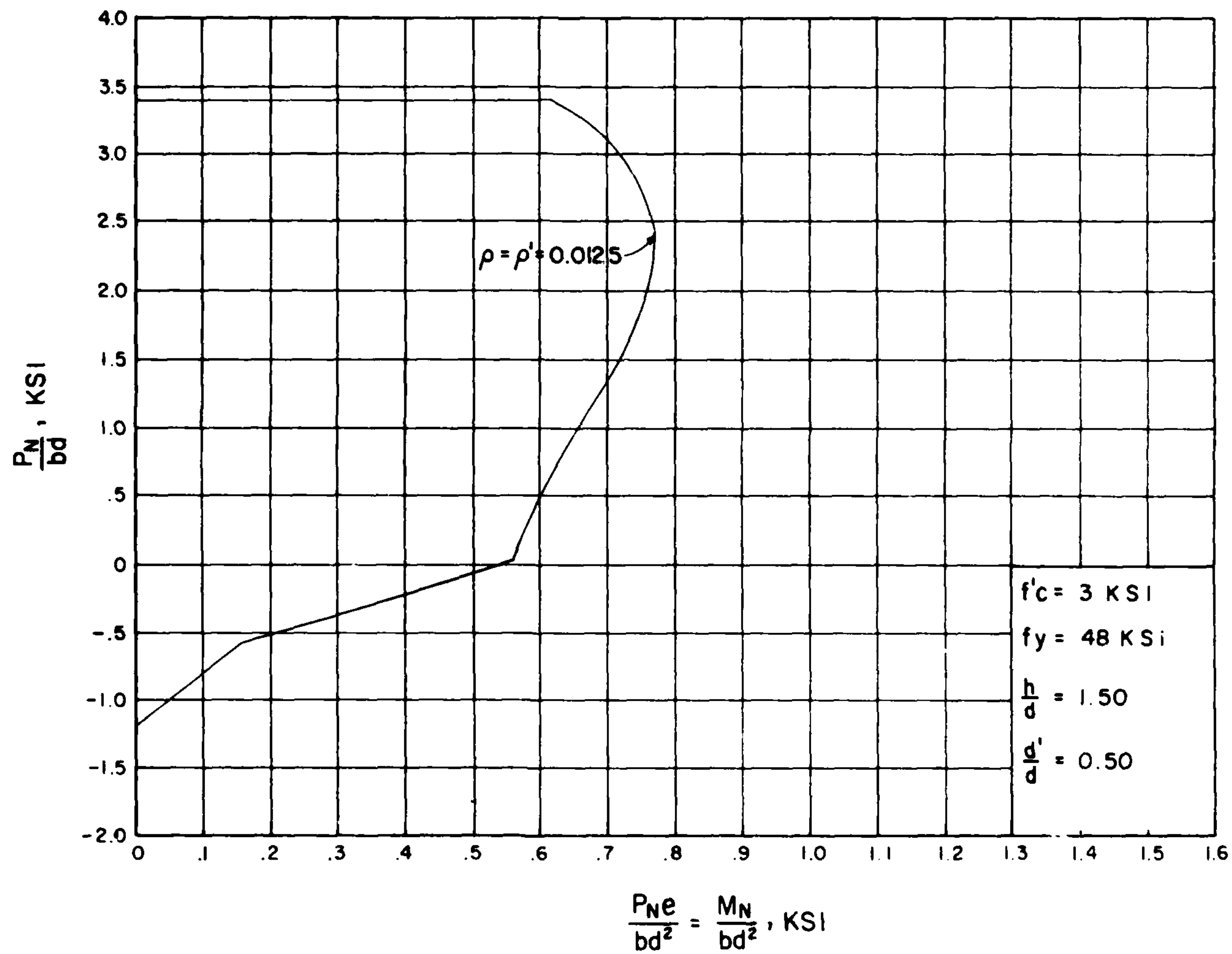


Figure 83. Load-moment strength interaction diagram for double reinforced members (f'_c = 3 ksi, f_y = 48 ksi, h/d = 1.50, and d'/d = 0.50)

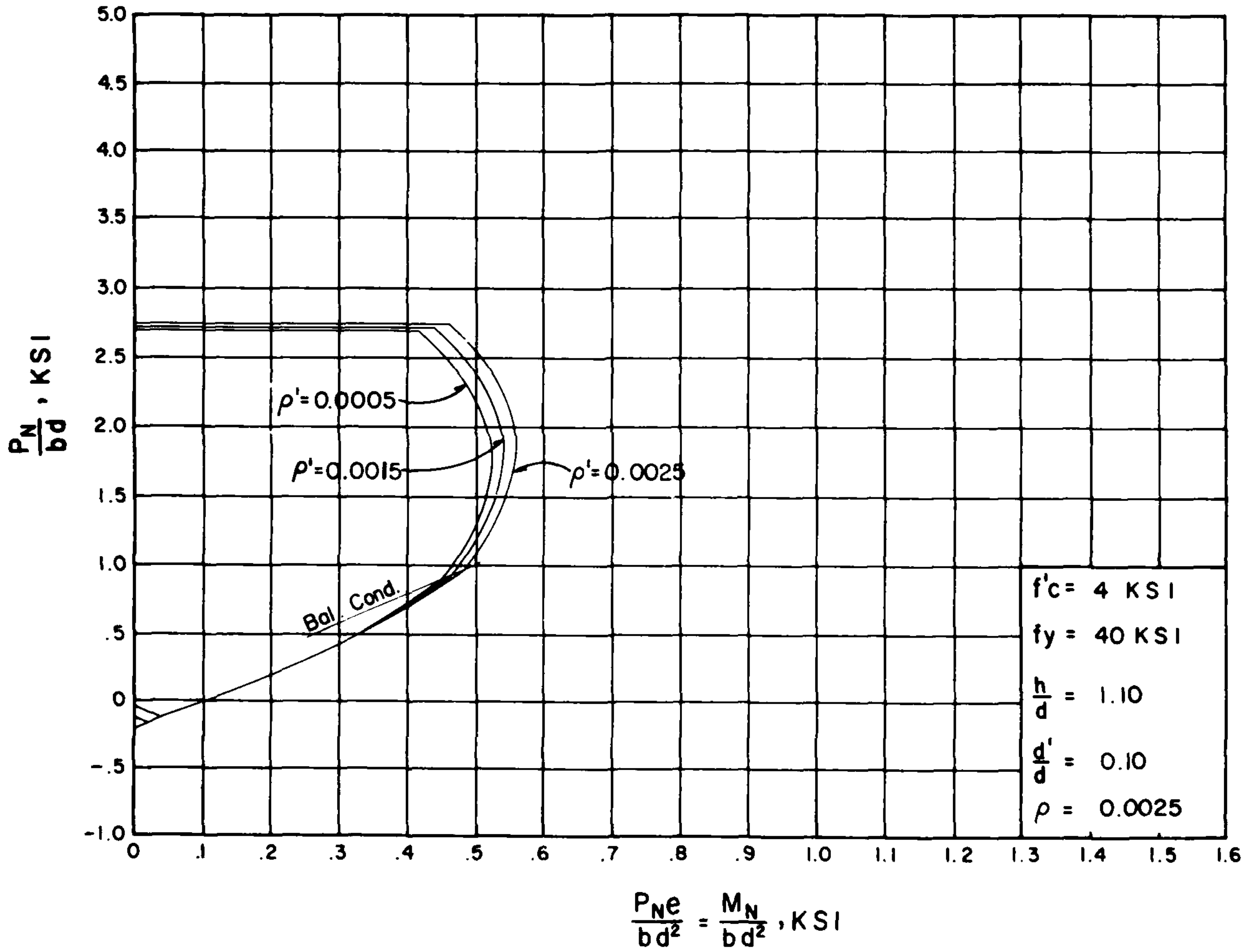


Figure 84. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0025)

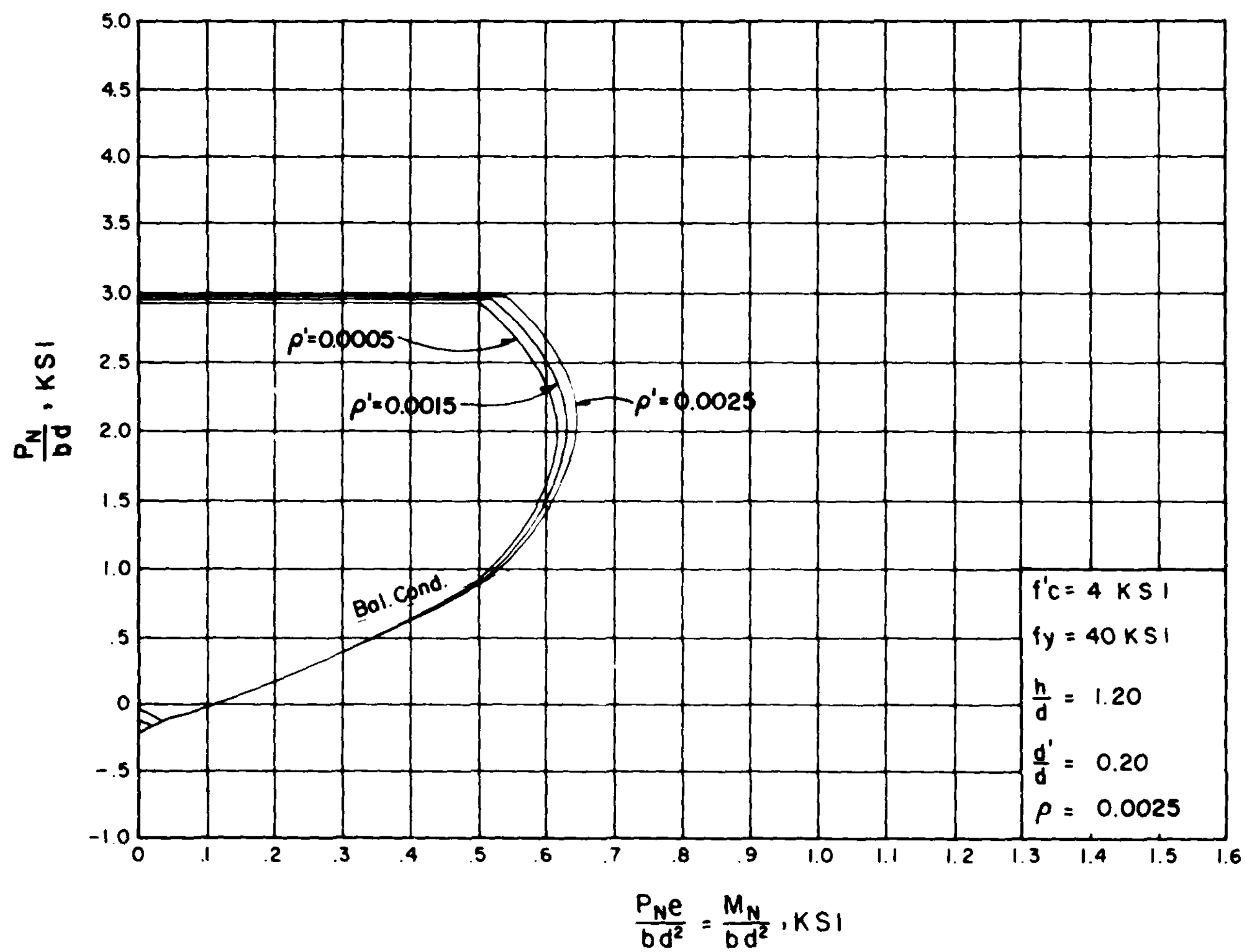


Figure 85. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0025)

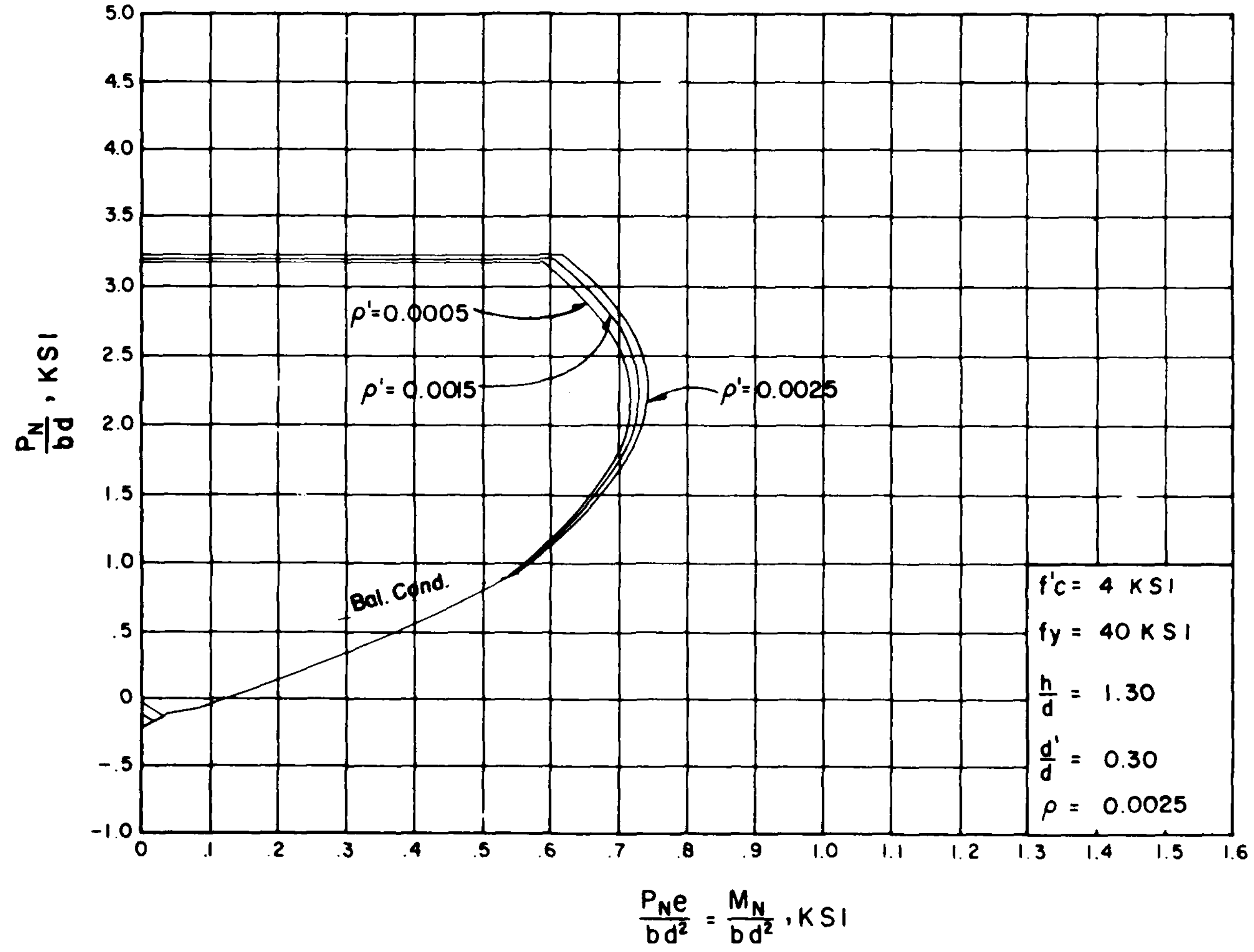


Figure 86. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0025)

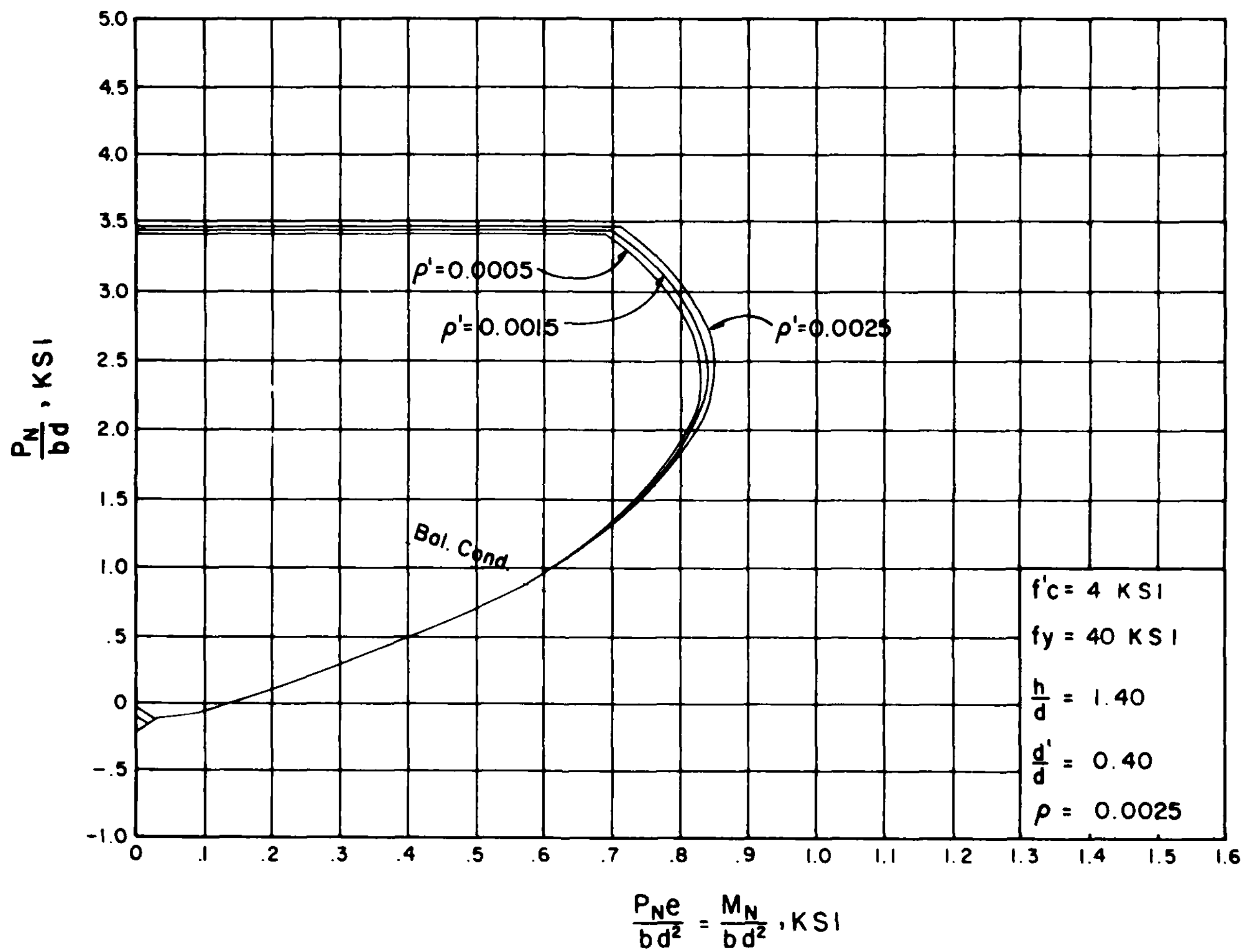


Figure 87. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0025)

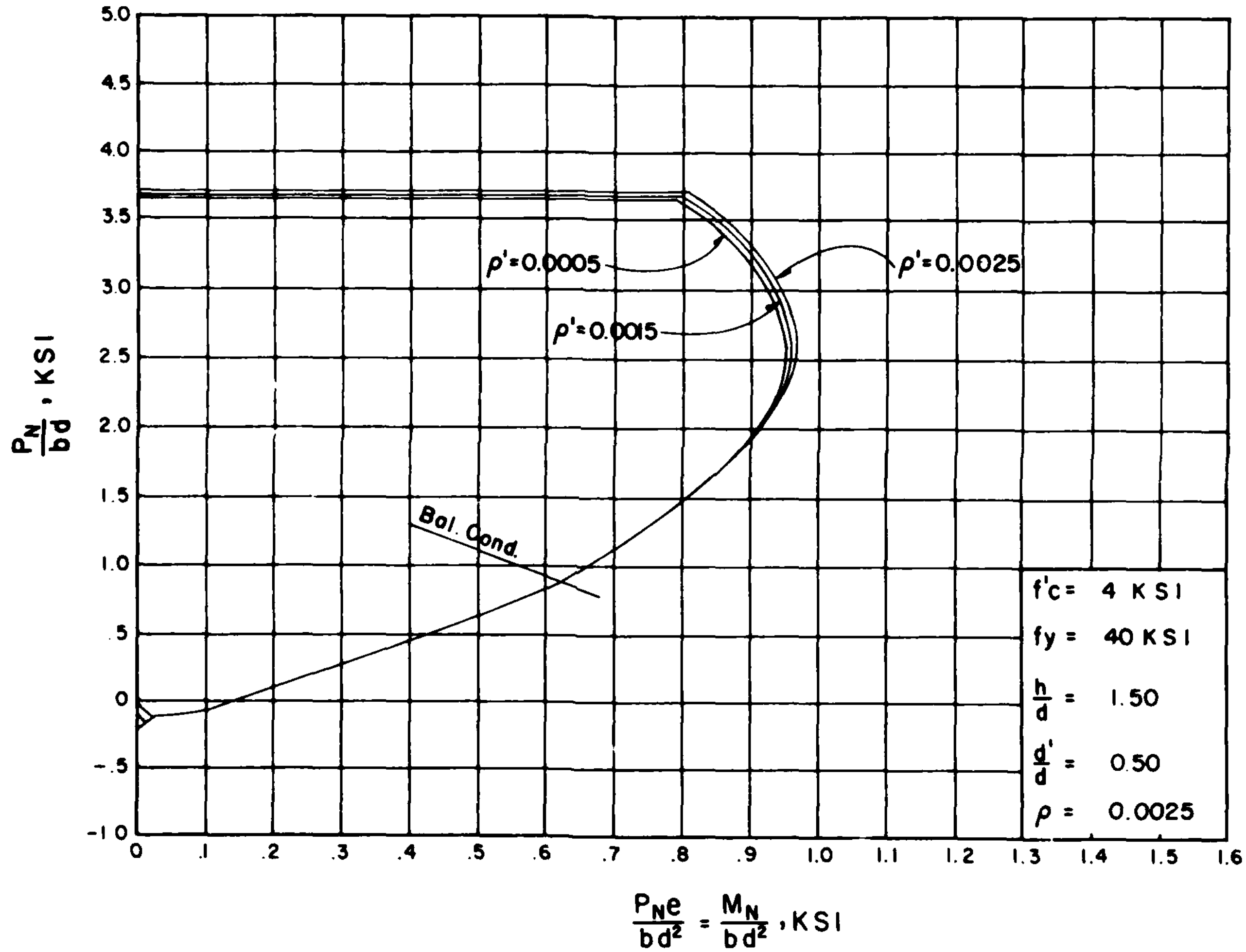


Figure 88. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0025)

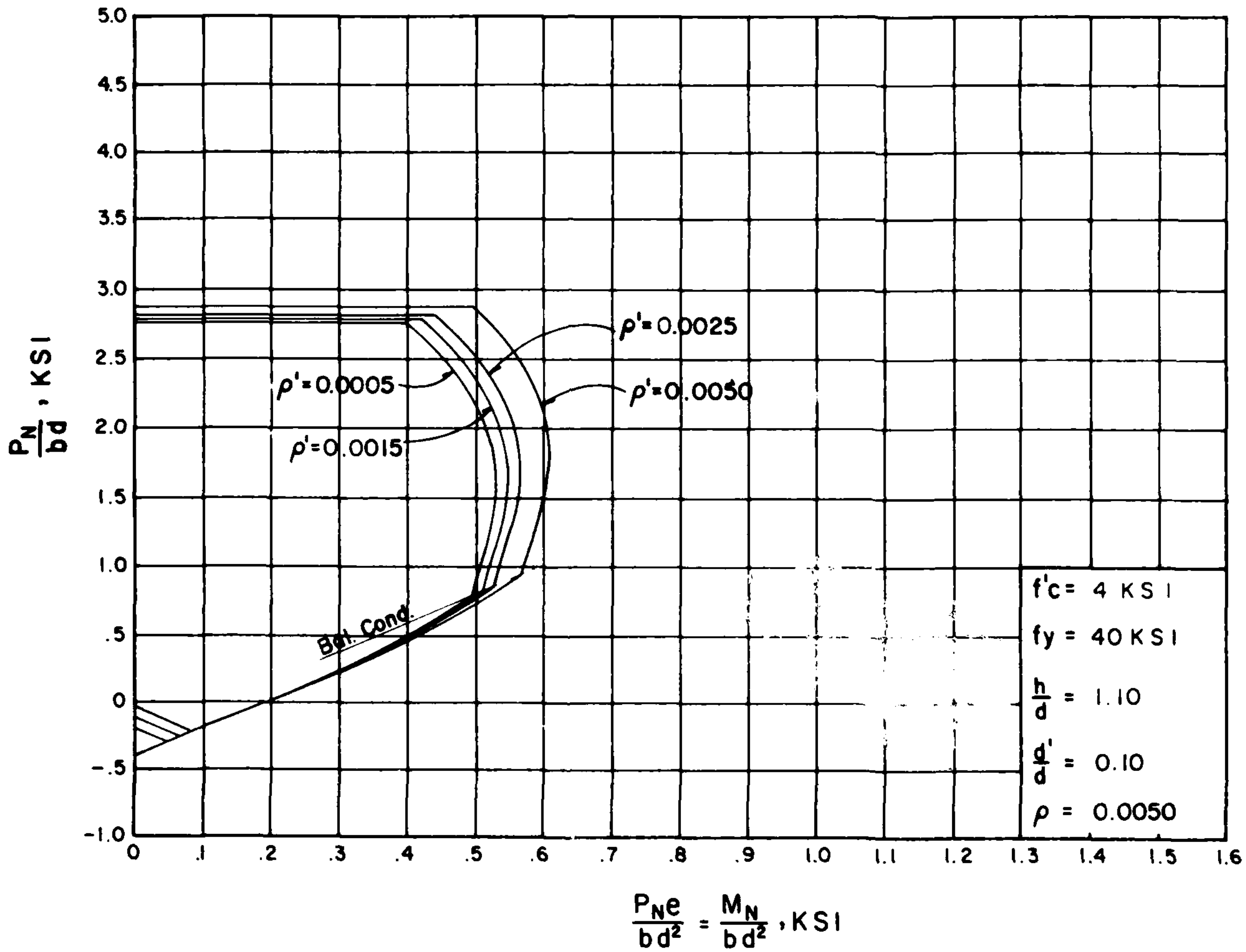


Figure 89. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0050)

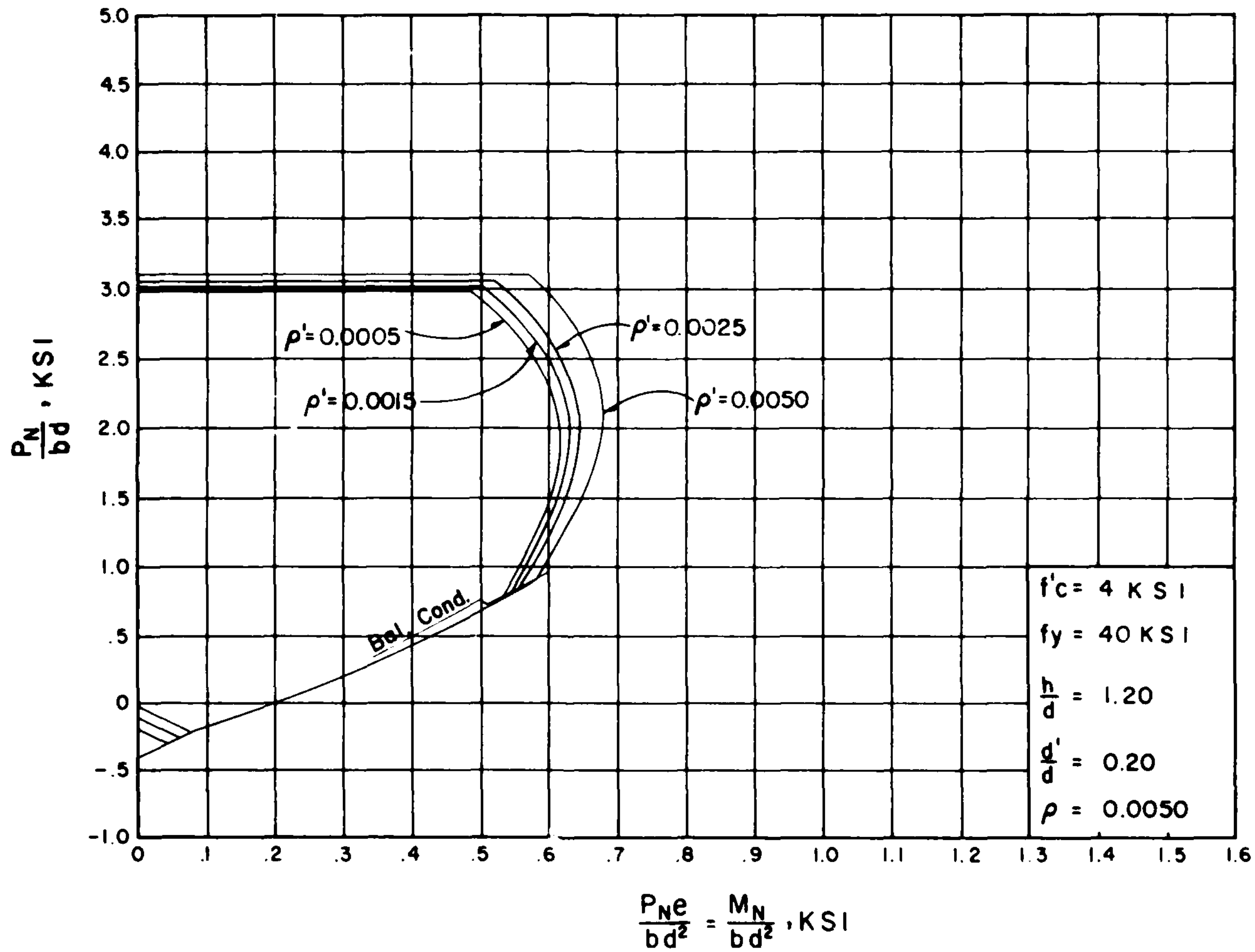


Figure 90. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0050)

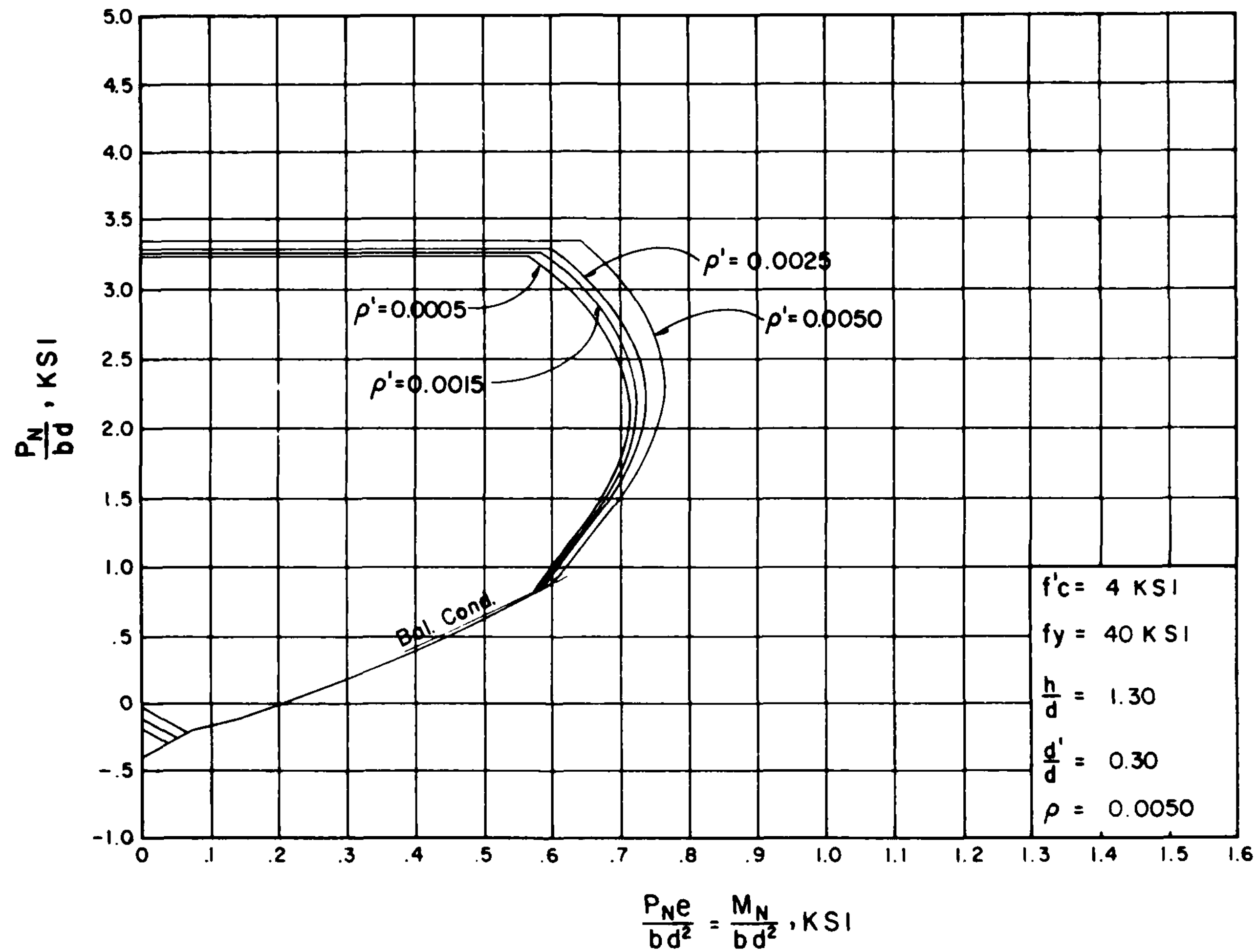


Figure 91. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0050)

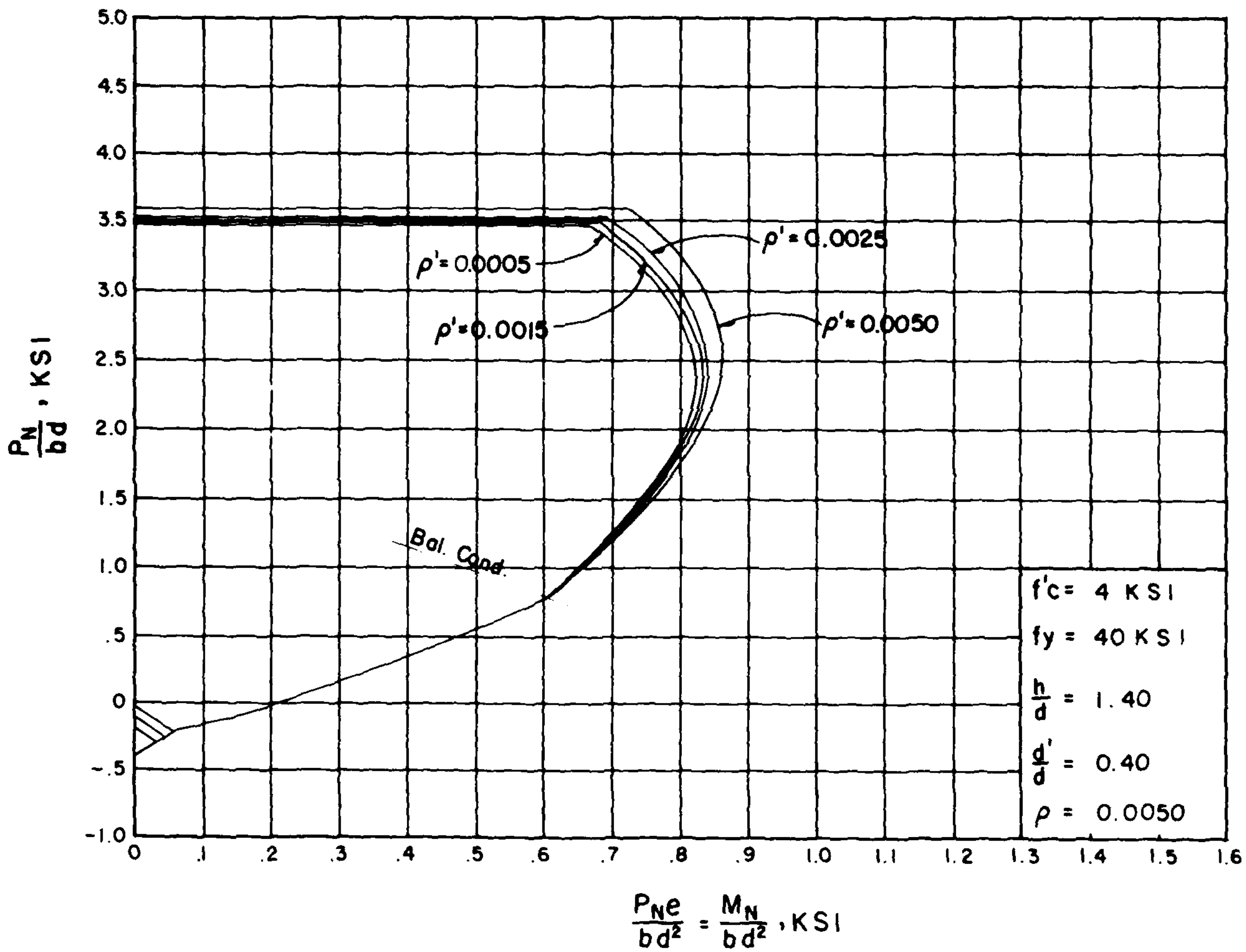


Figure 92. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0050)

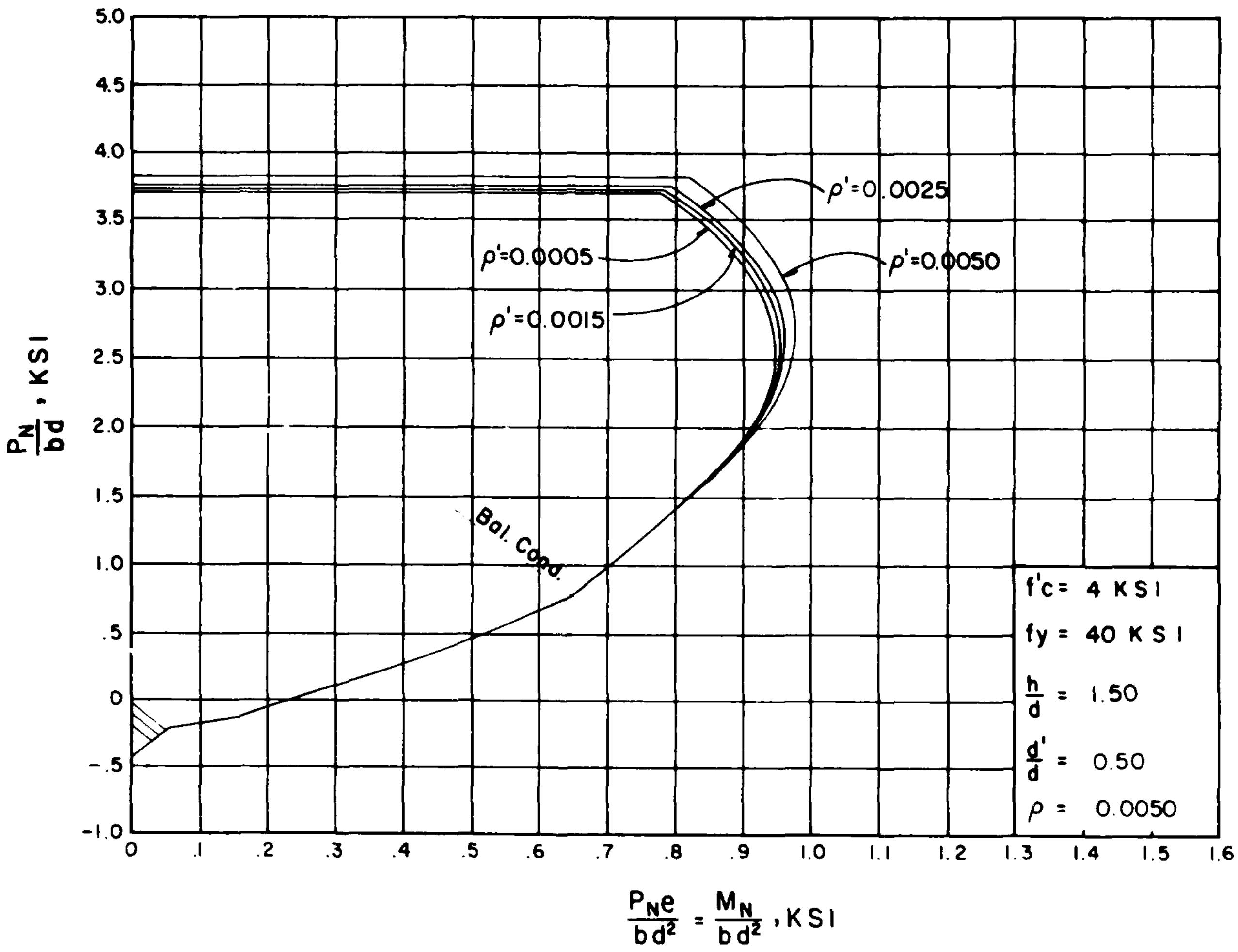


Figure 93. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0050)

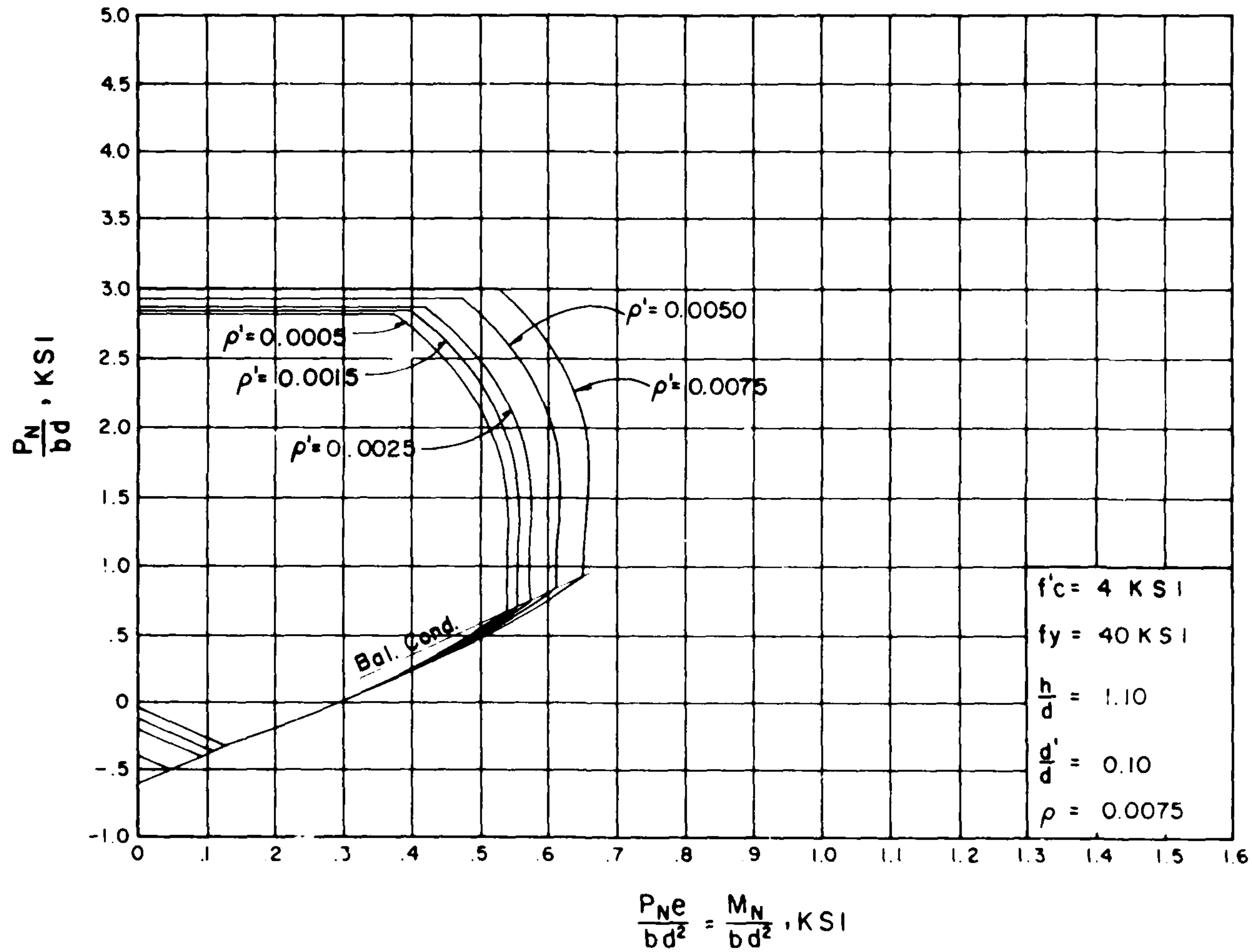


Figure 94. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0075)

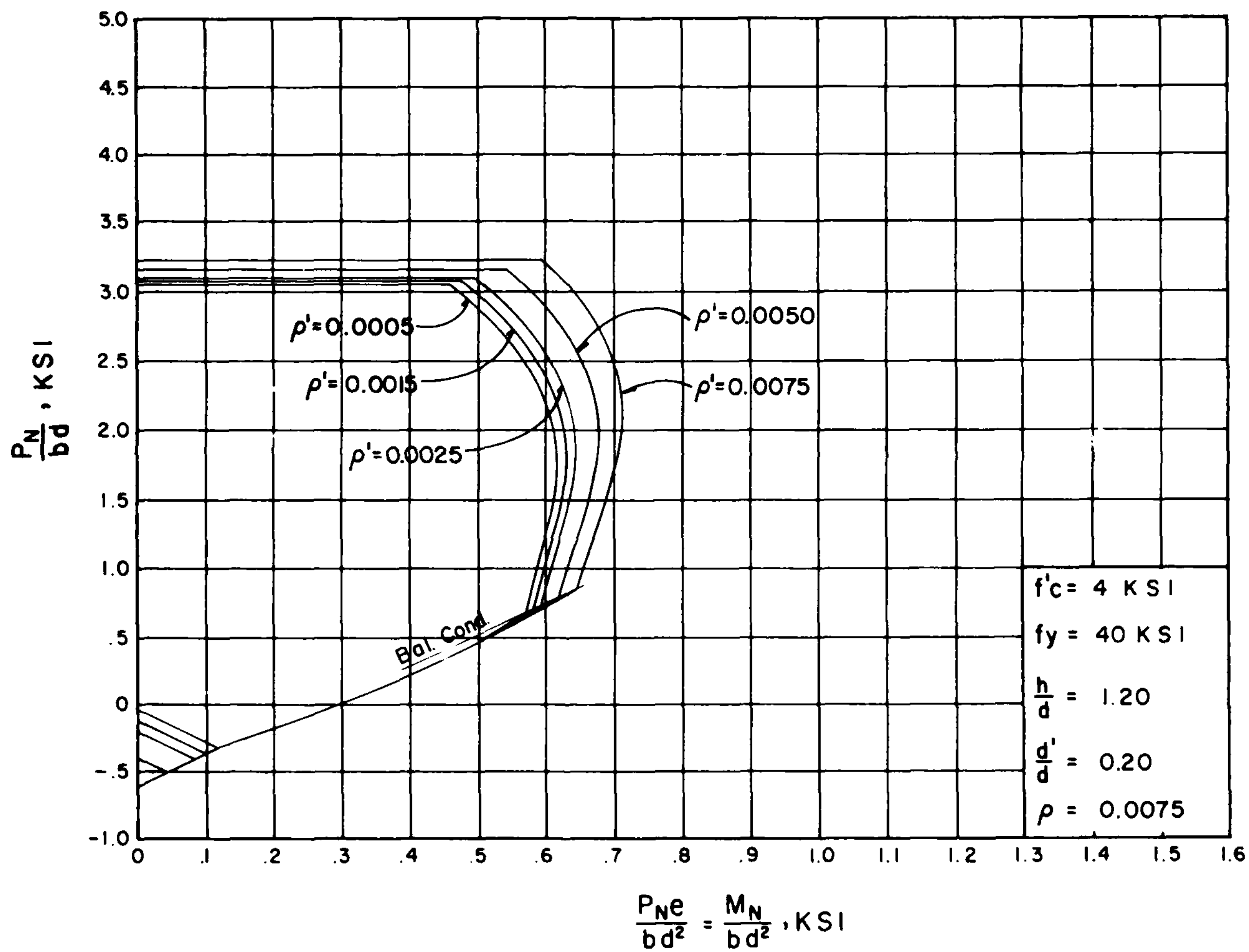


Figure 95. Load-moment strength interaction diagram for double reinforced members ($f'_c = 4$ ksi, $f_y = 40$ ksi, $h/d = 1.20$, $d'/d = 0.20$, and $\rho = 0.0075$)

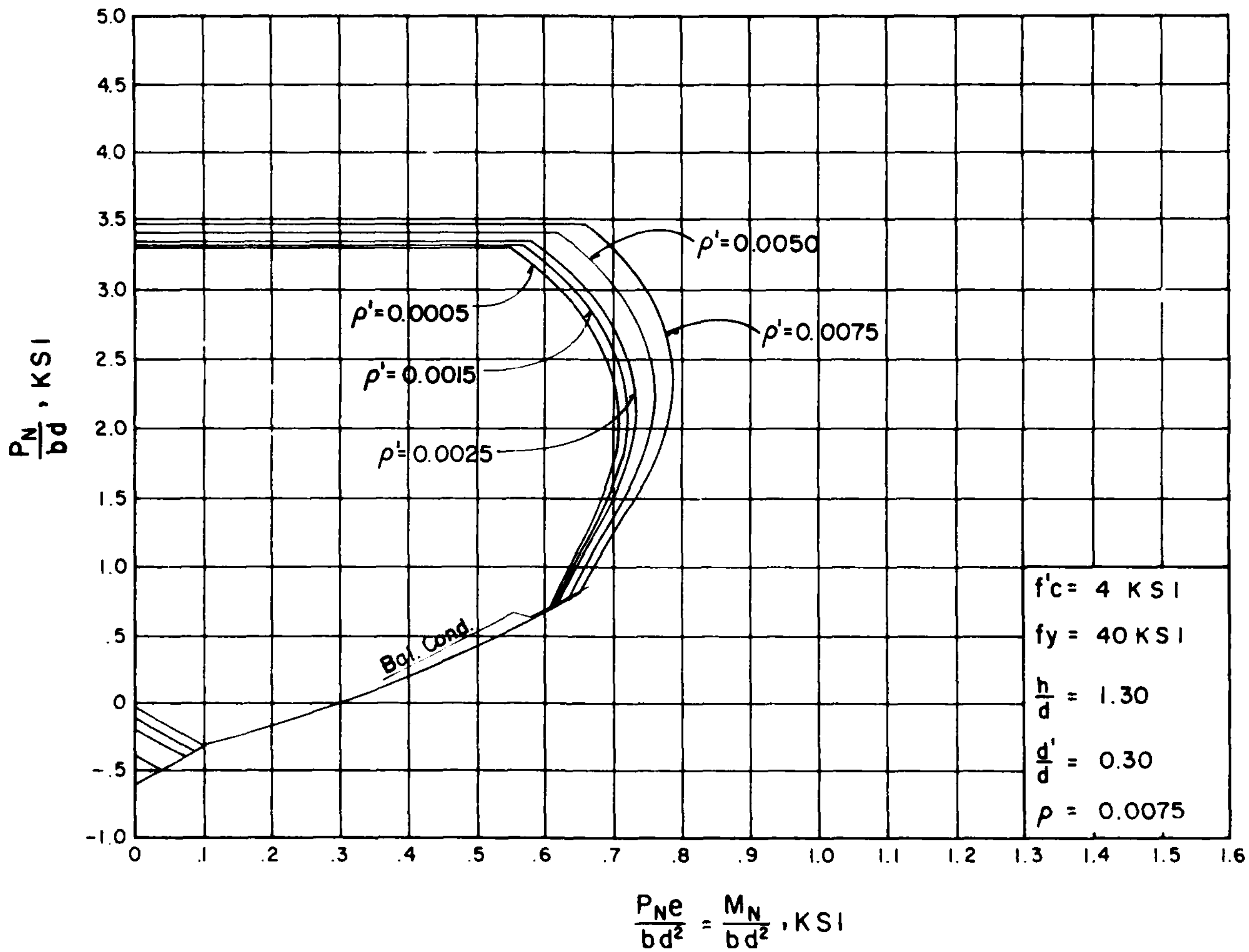


Figure 96. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0075)

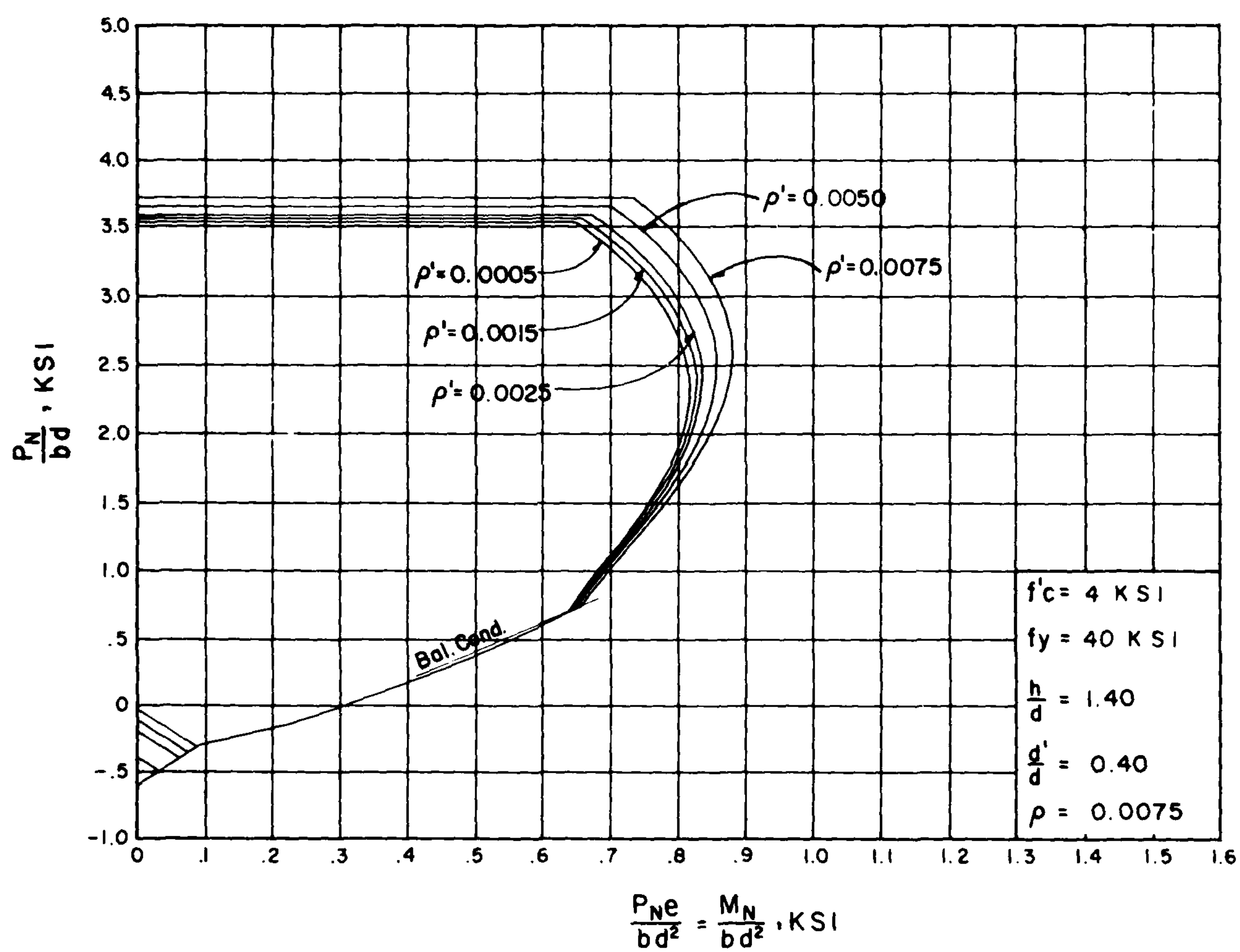


Figure 97. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0075)

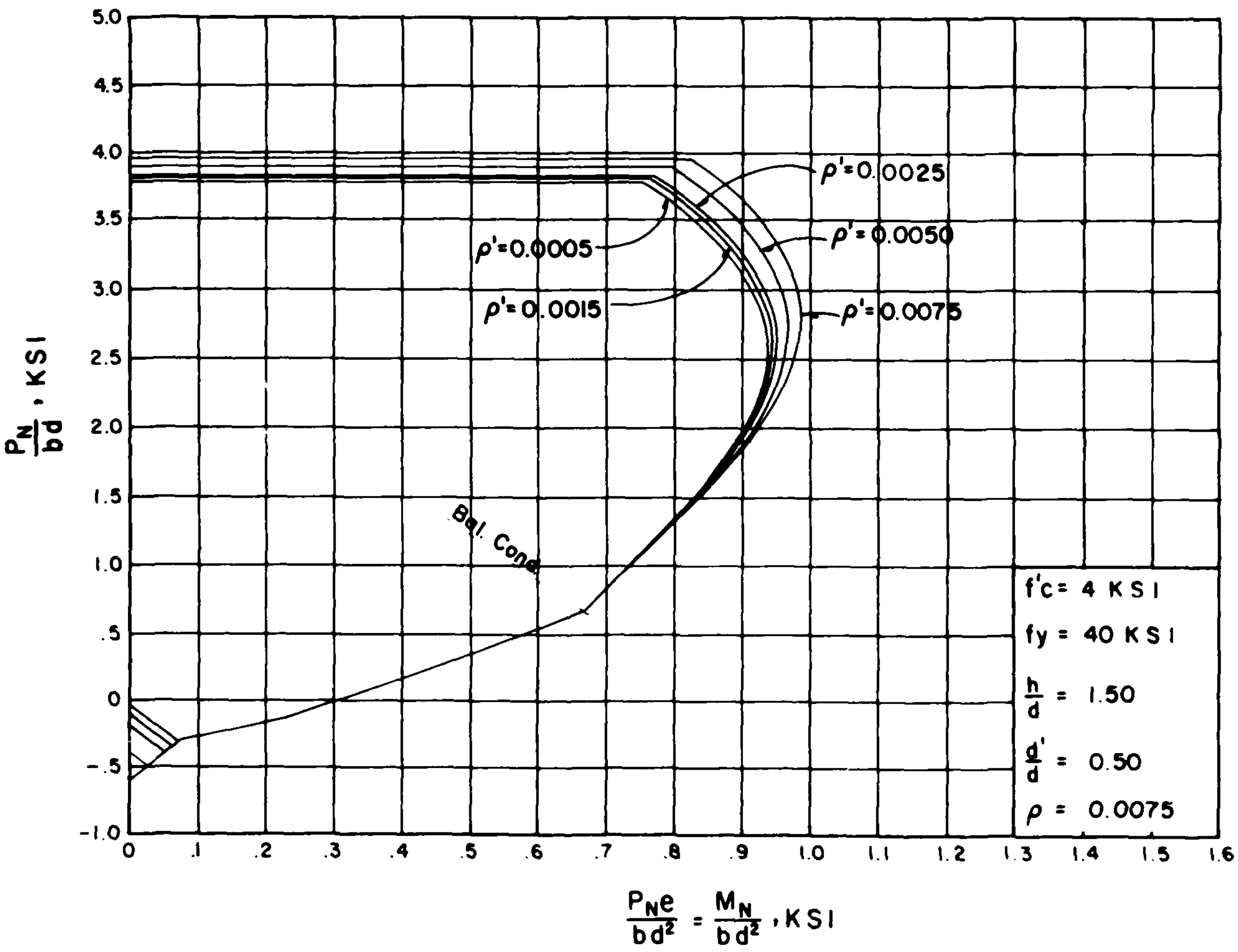


Figure 98. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0075)

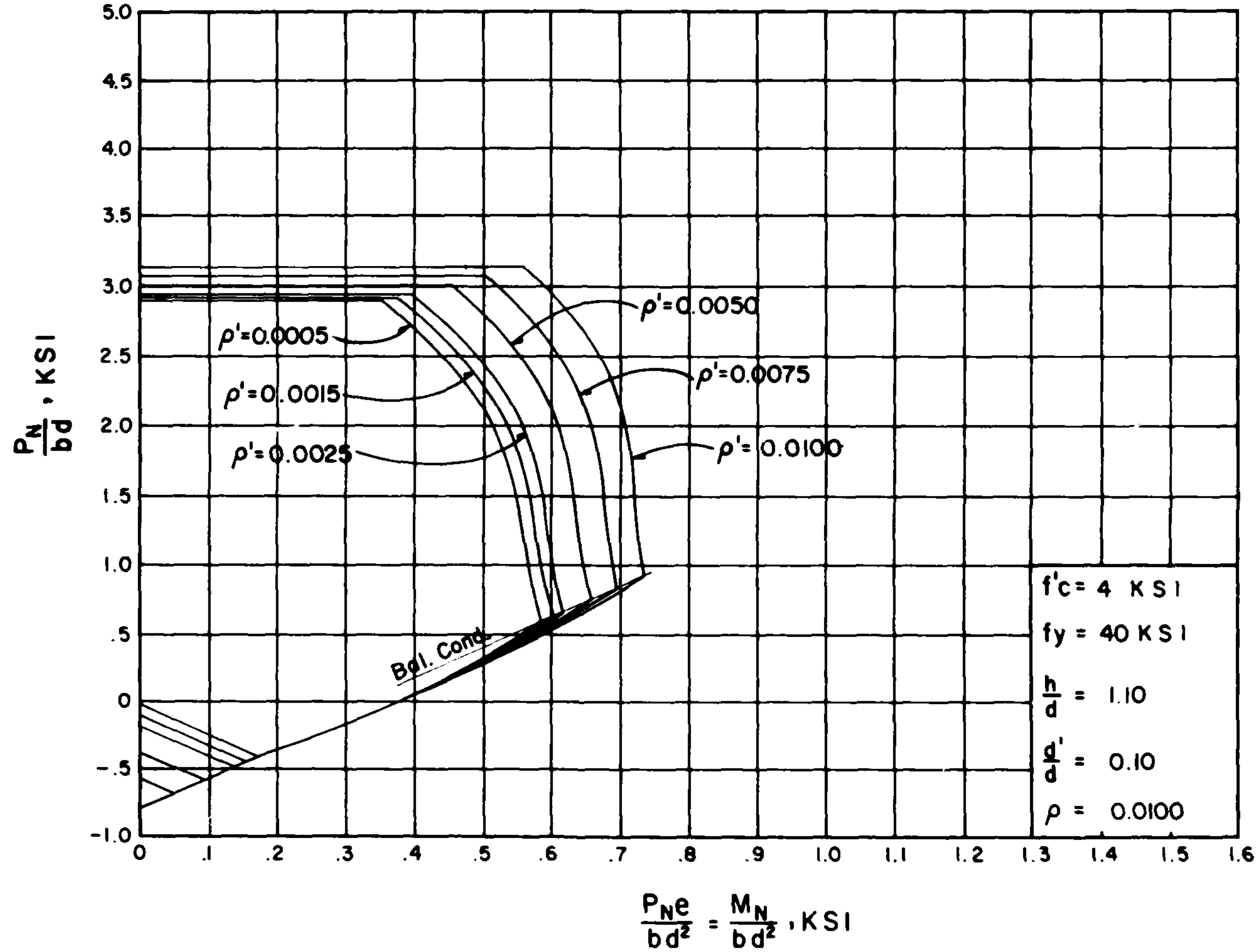


Figure 99. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0100)

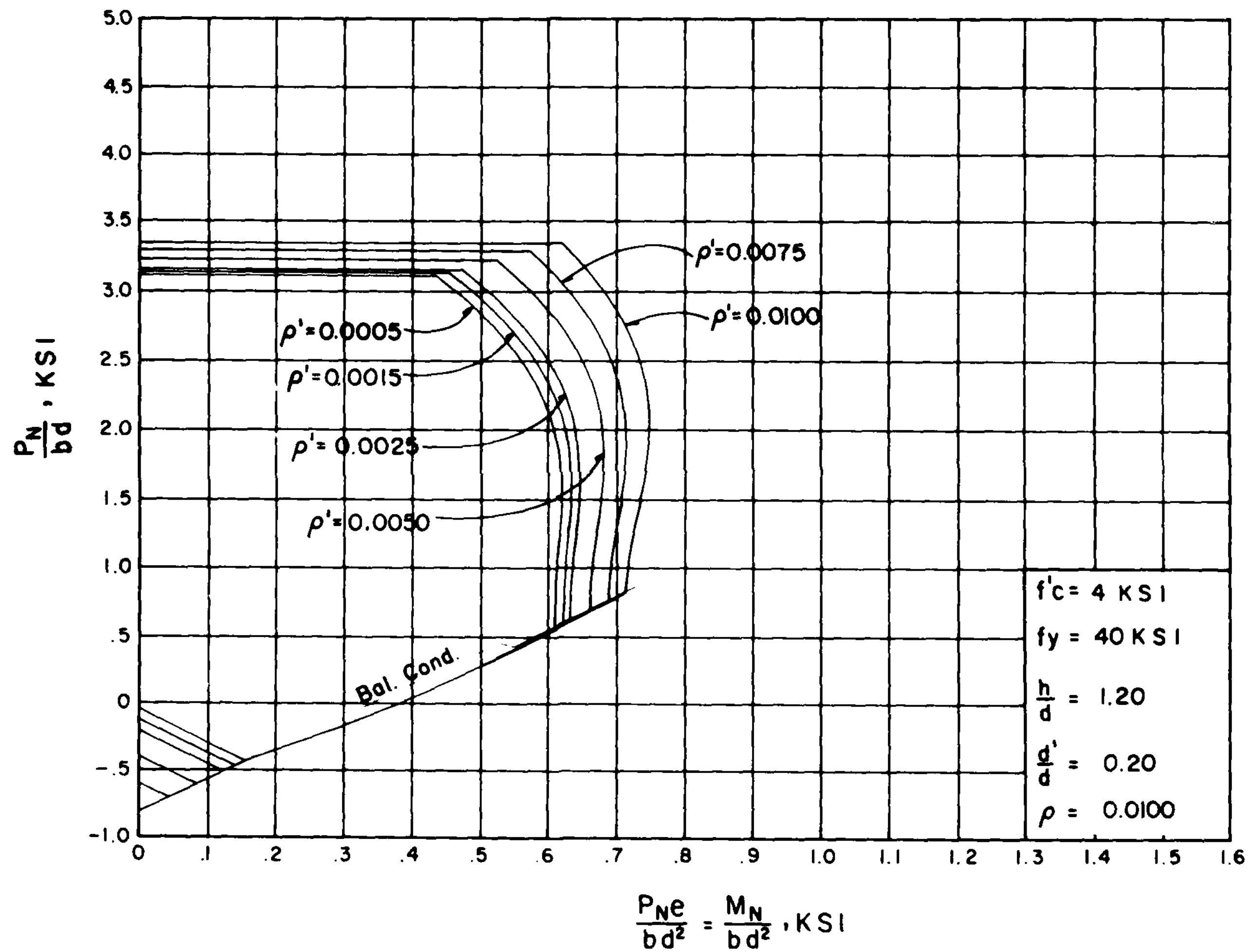


Figure 100. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0100)

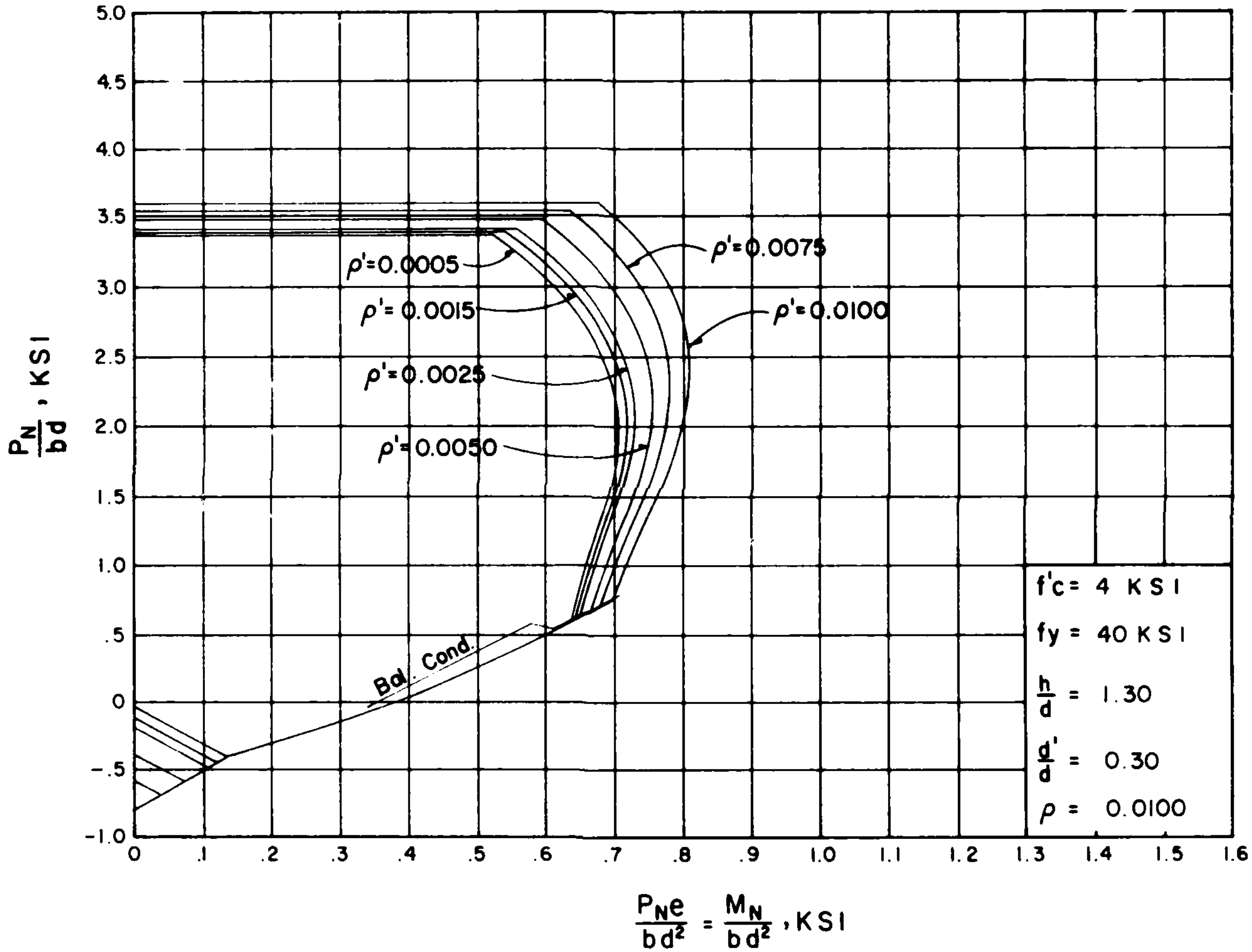


Figure 101. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0100)

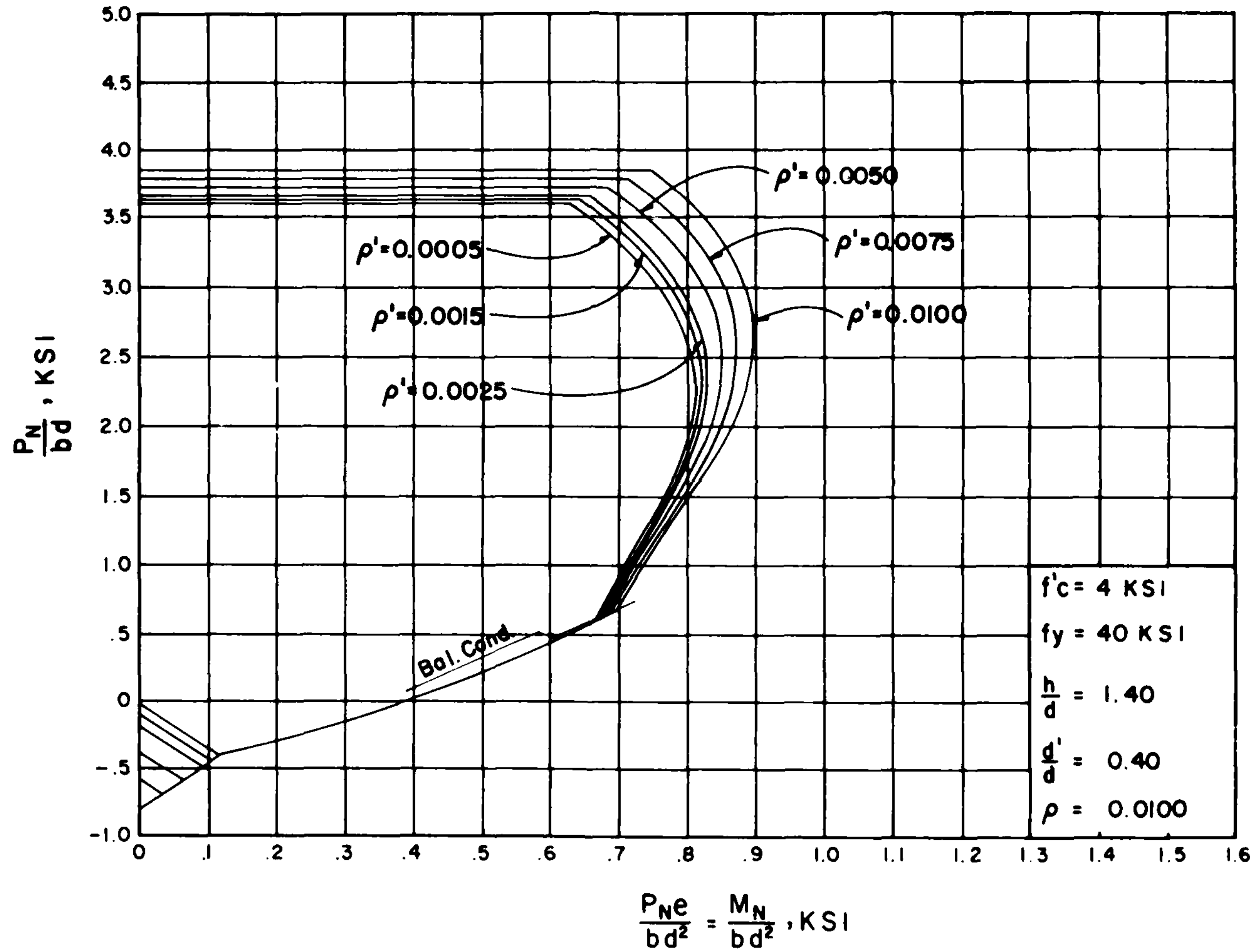


Figure 102. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0100)

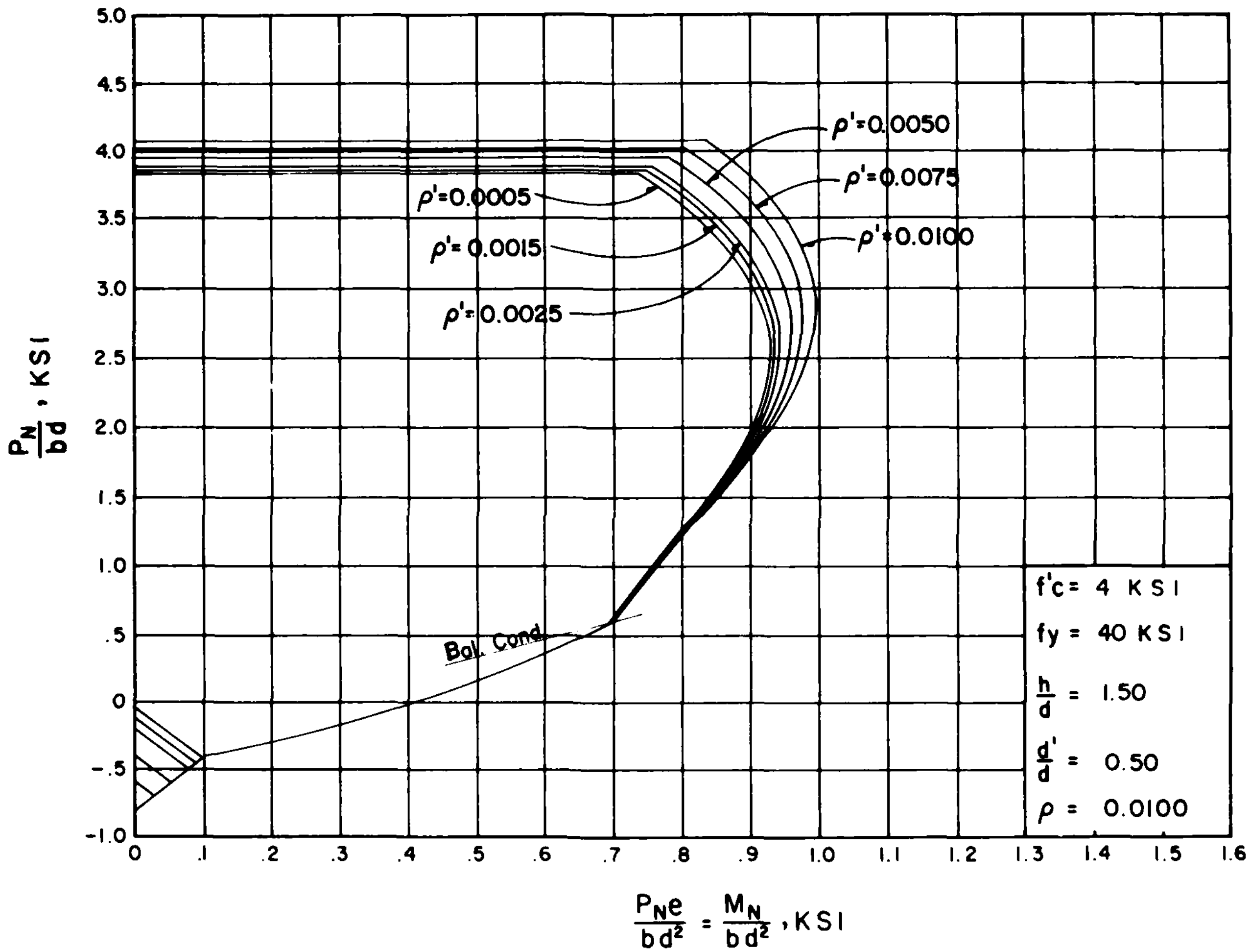


Figure 103. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0100)

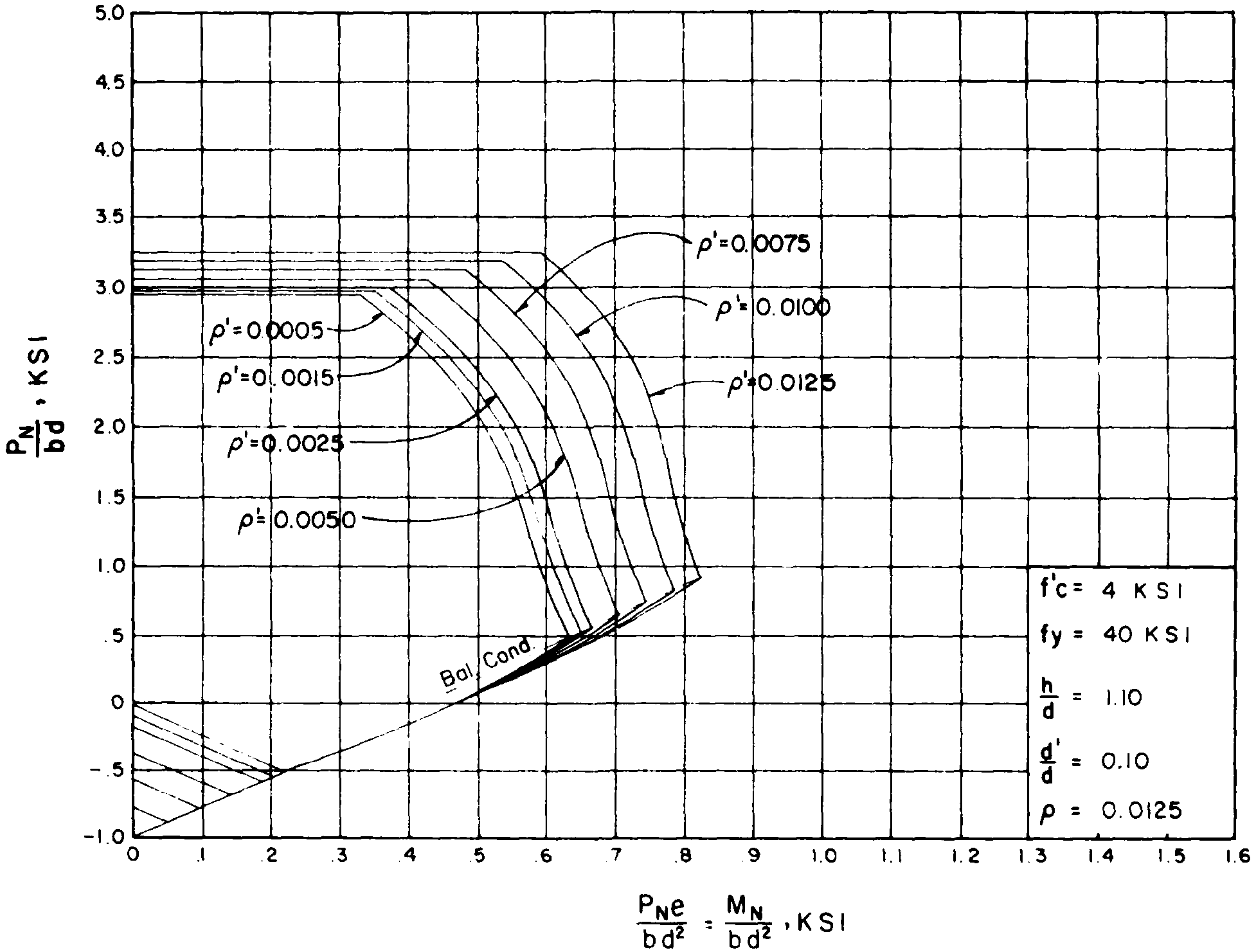


Figure 104. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0125)

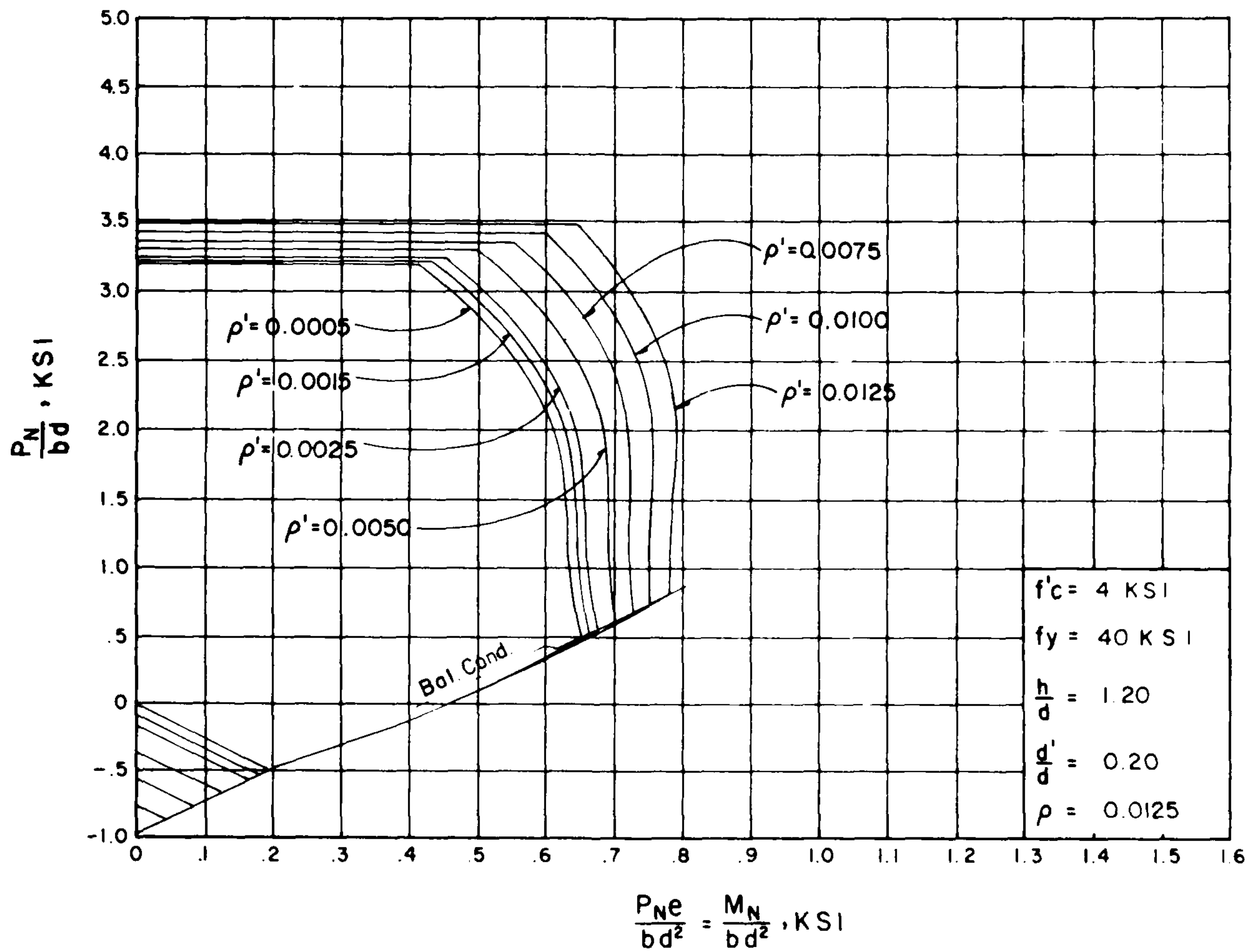


Figure 105. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0125)

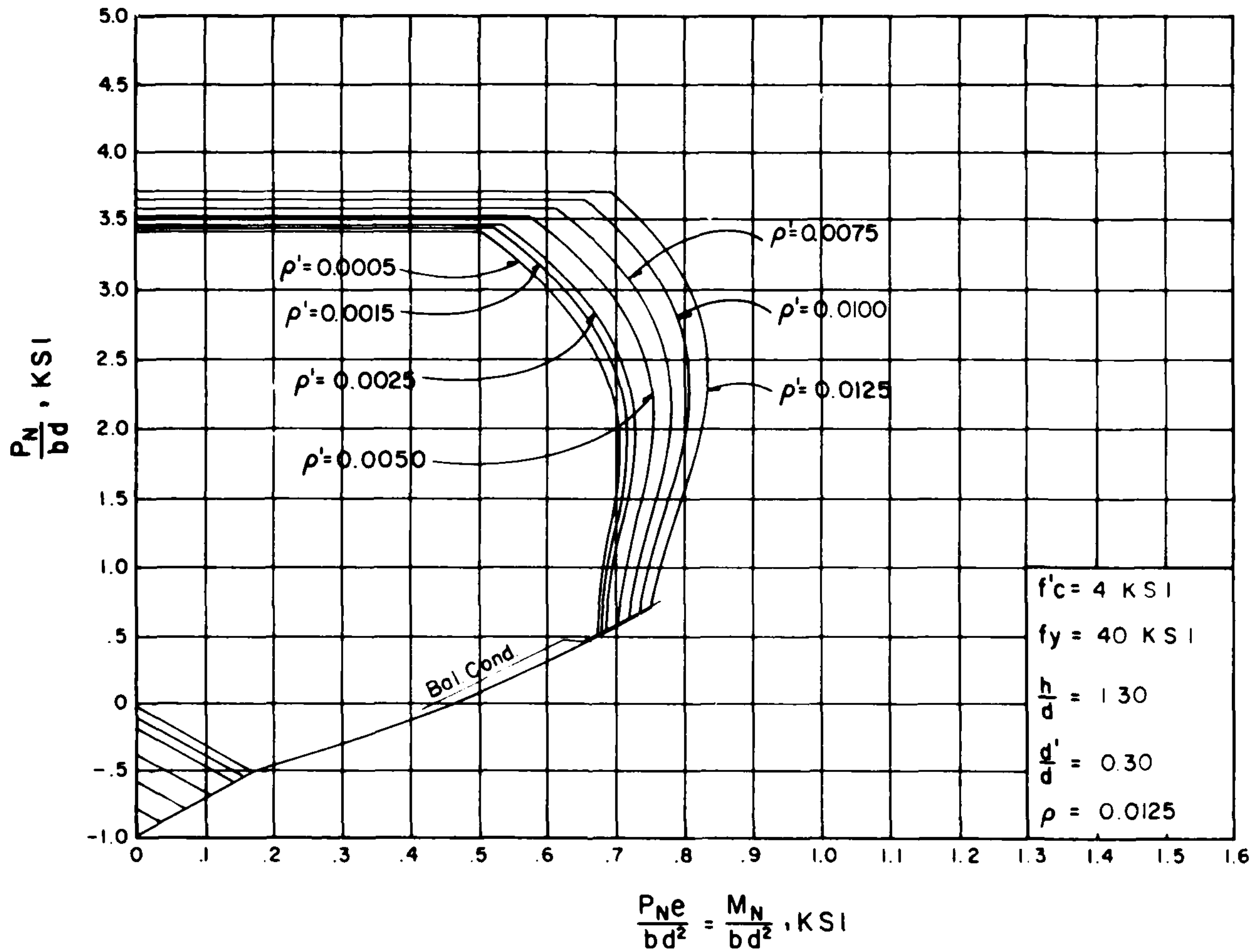


Figure 106. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0125)

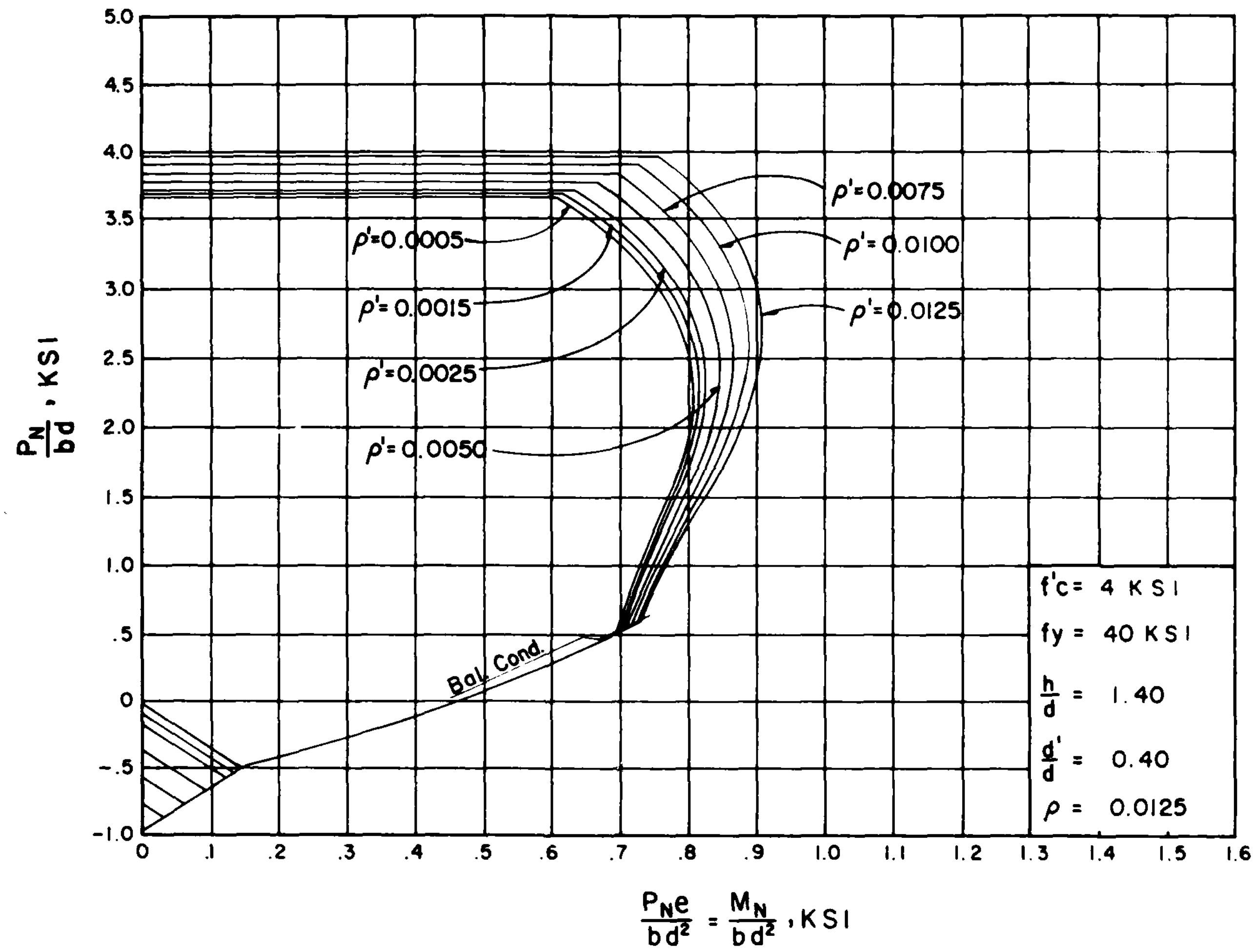


Figure 107. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0125)

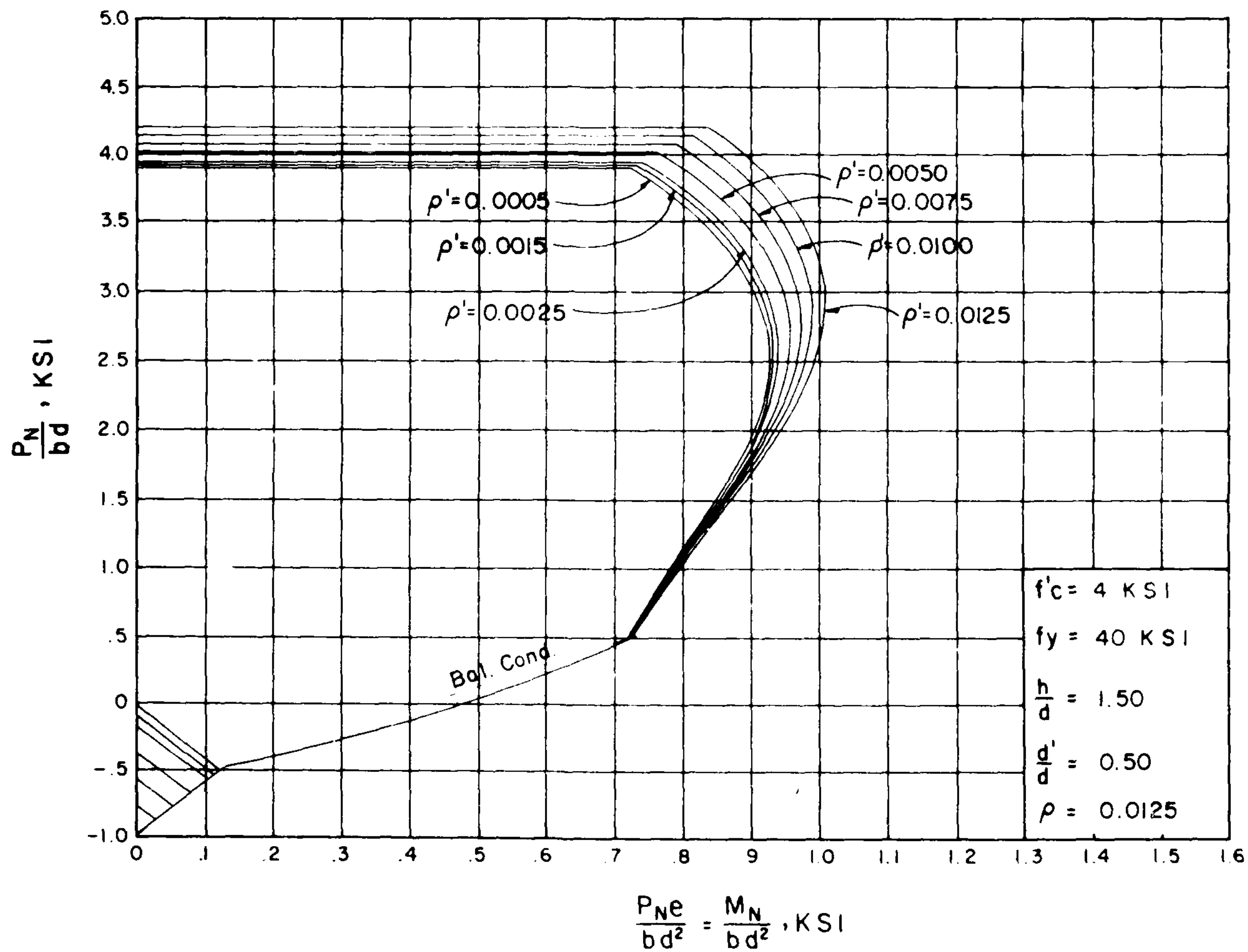


Figure 108. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0125)

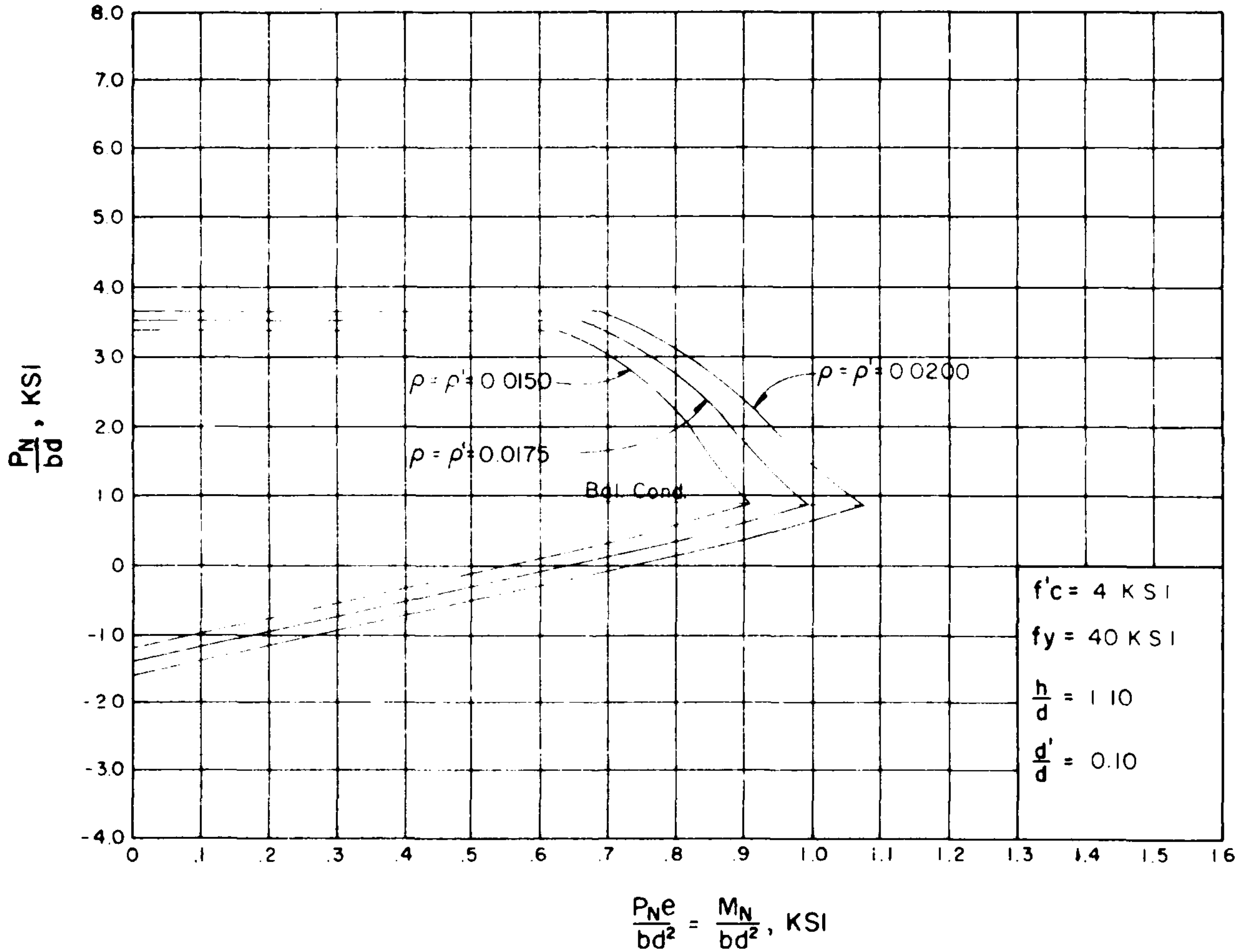


Figure 109. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.10, and d'/d = 0.10)

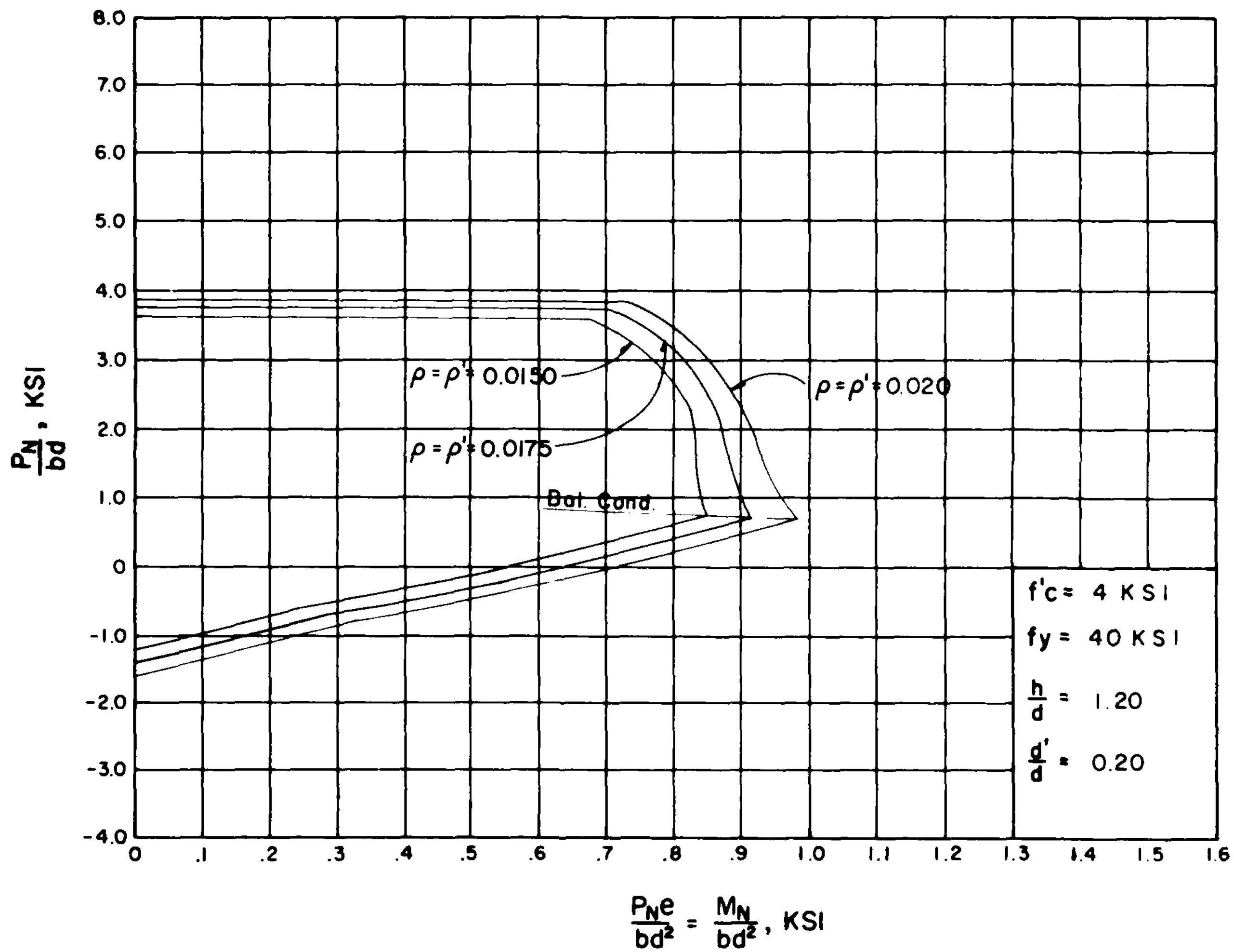


Figure 110. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.20, and d'/d = 0.20)

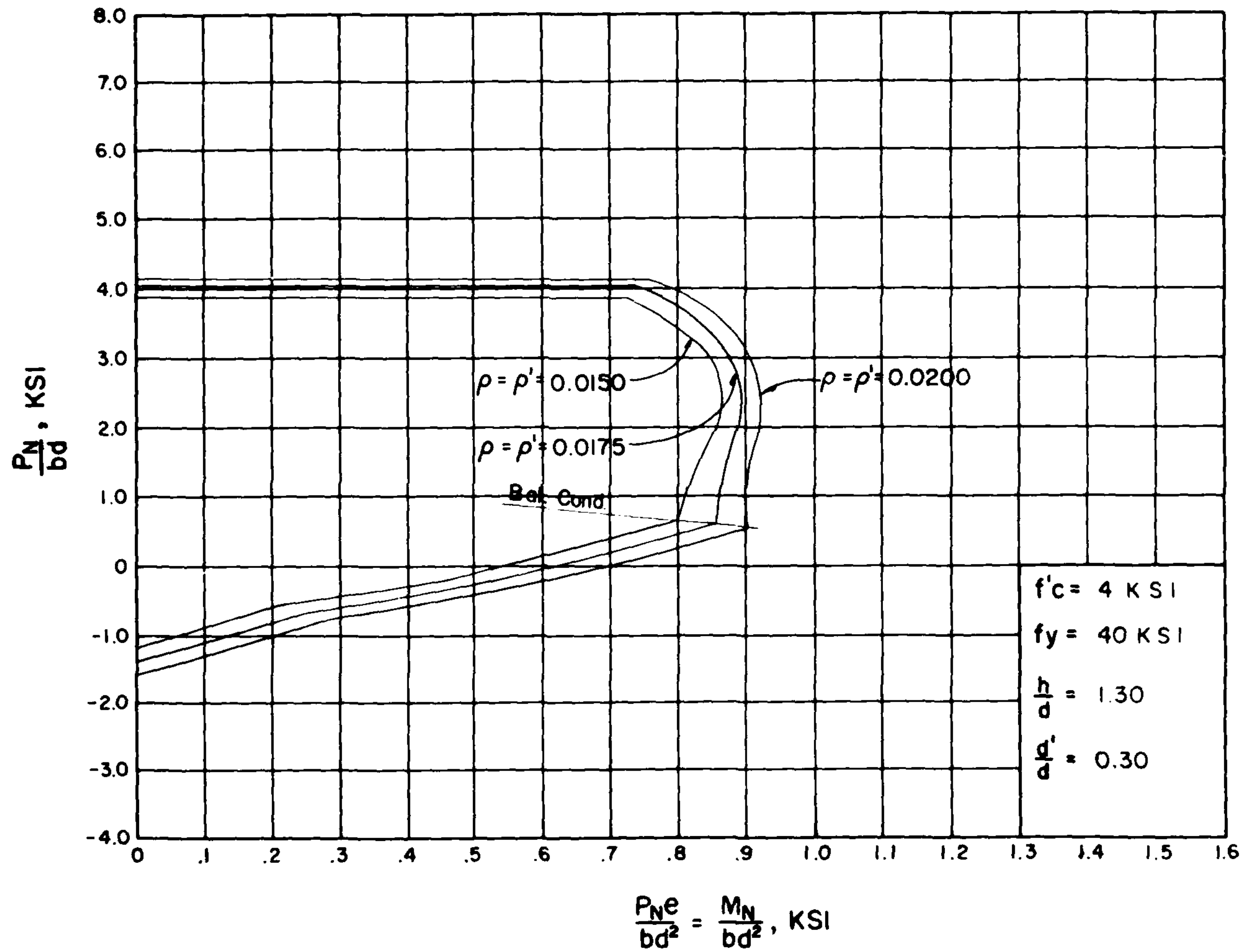


Figure 111. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.30, and d'/d = 0.30)

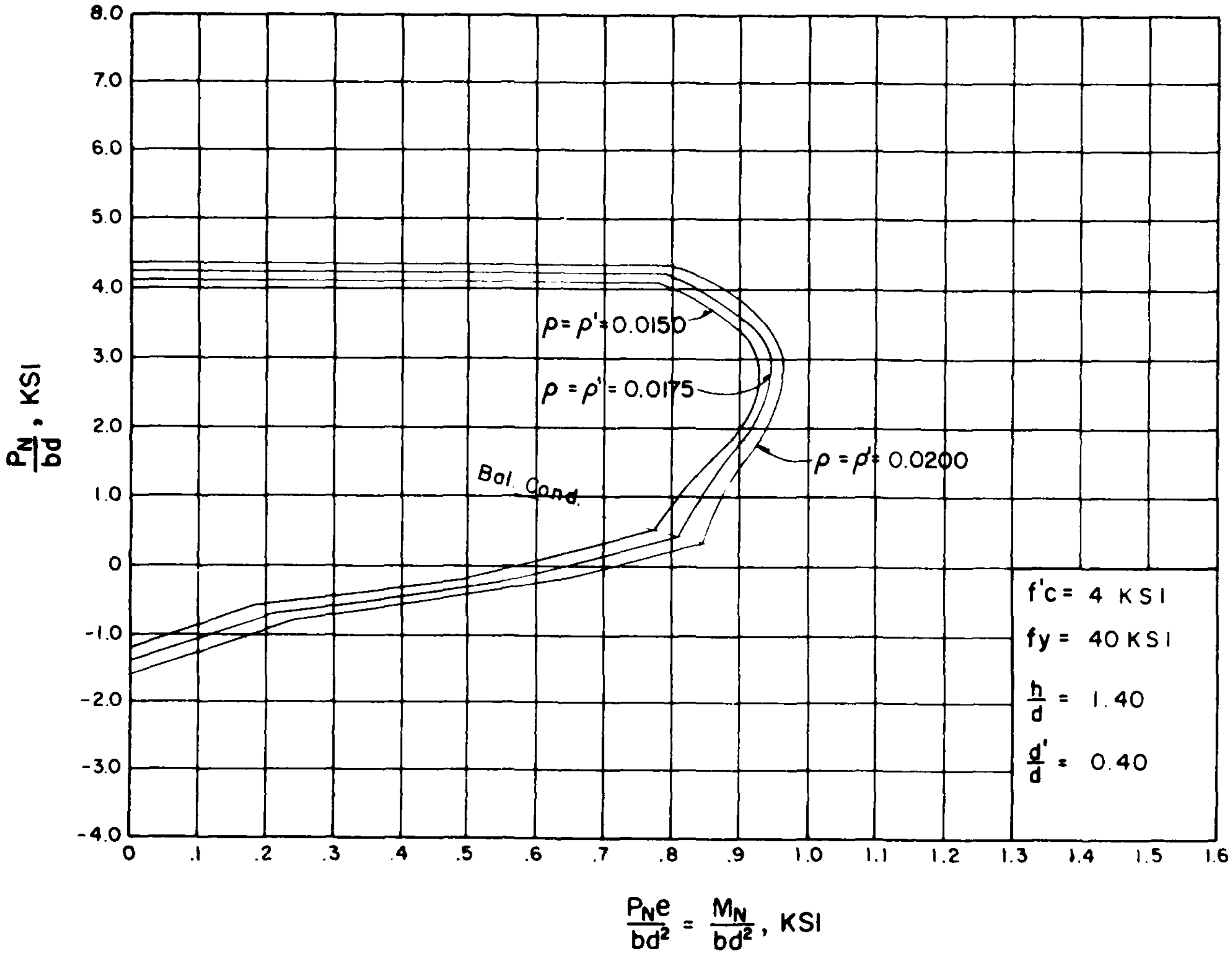


Figure 112. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.40, and d'/d = 0.40)

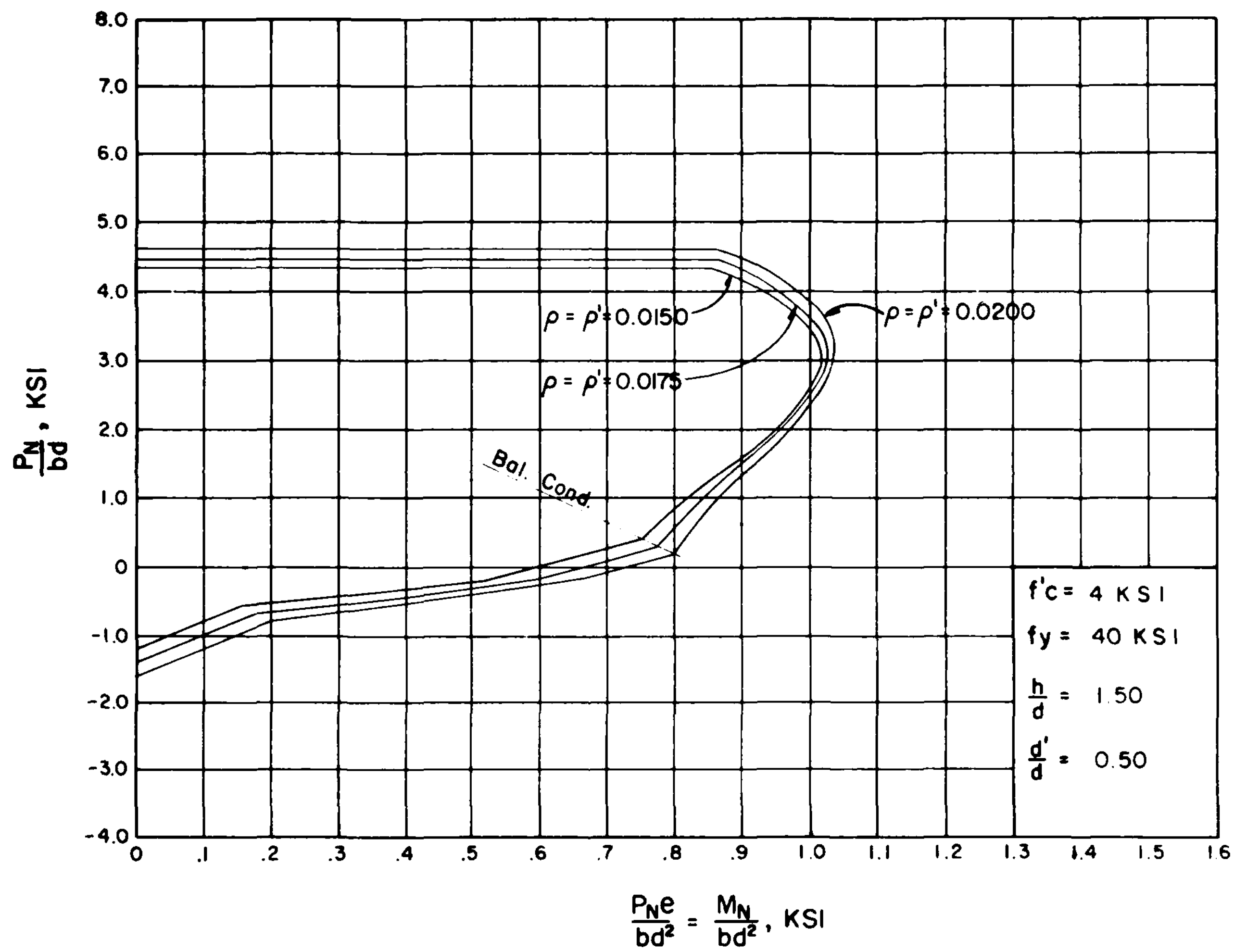


Figure 113. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 40 ksi, h/d = 1.50, and d'/d = 0.50)

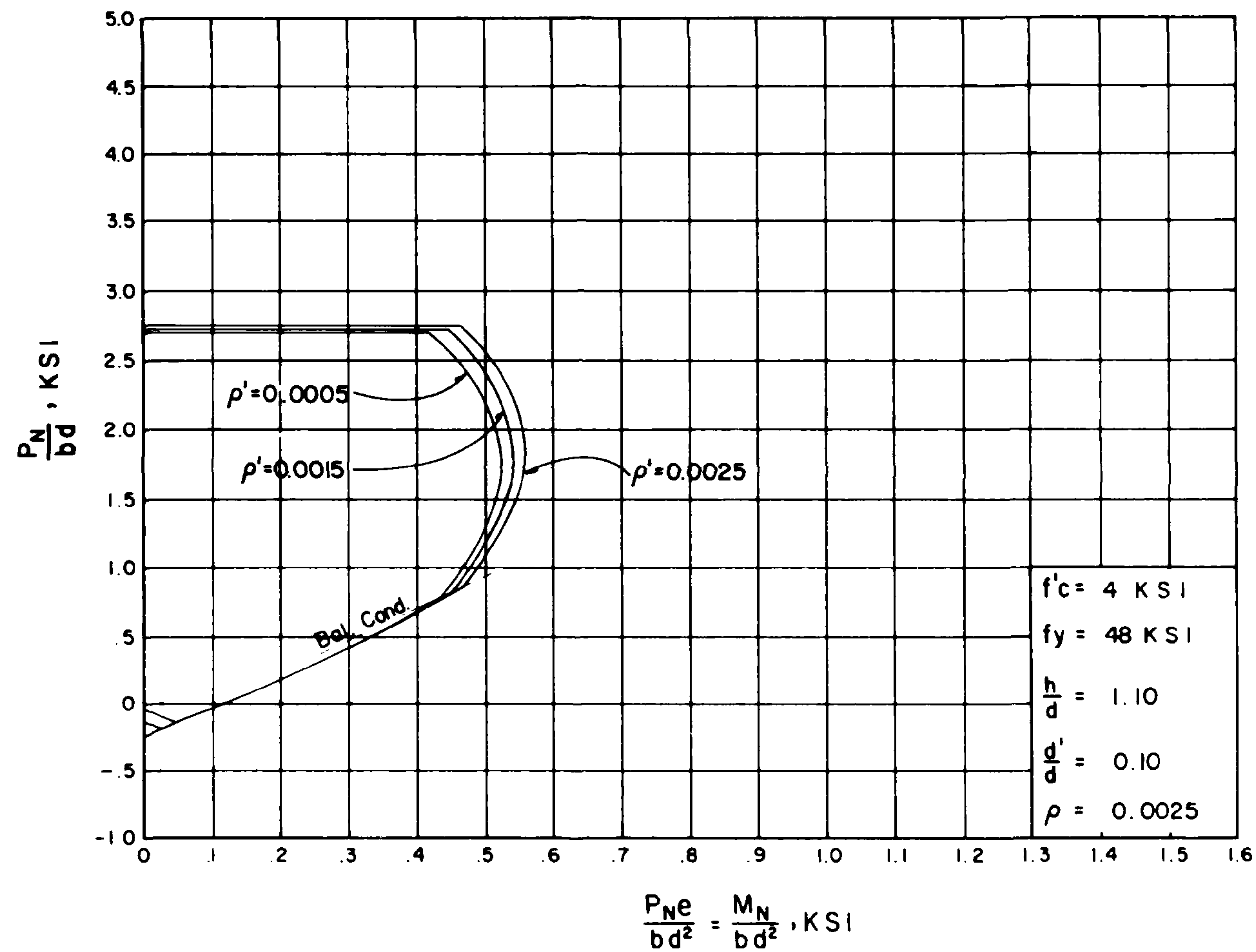


Figure 114. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0025)

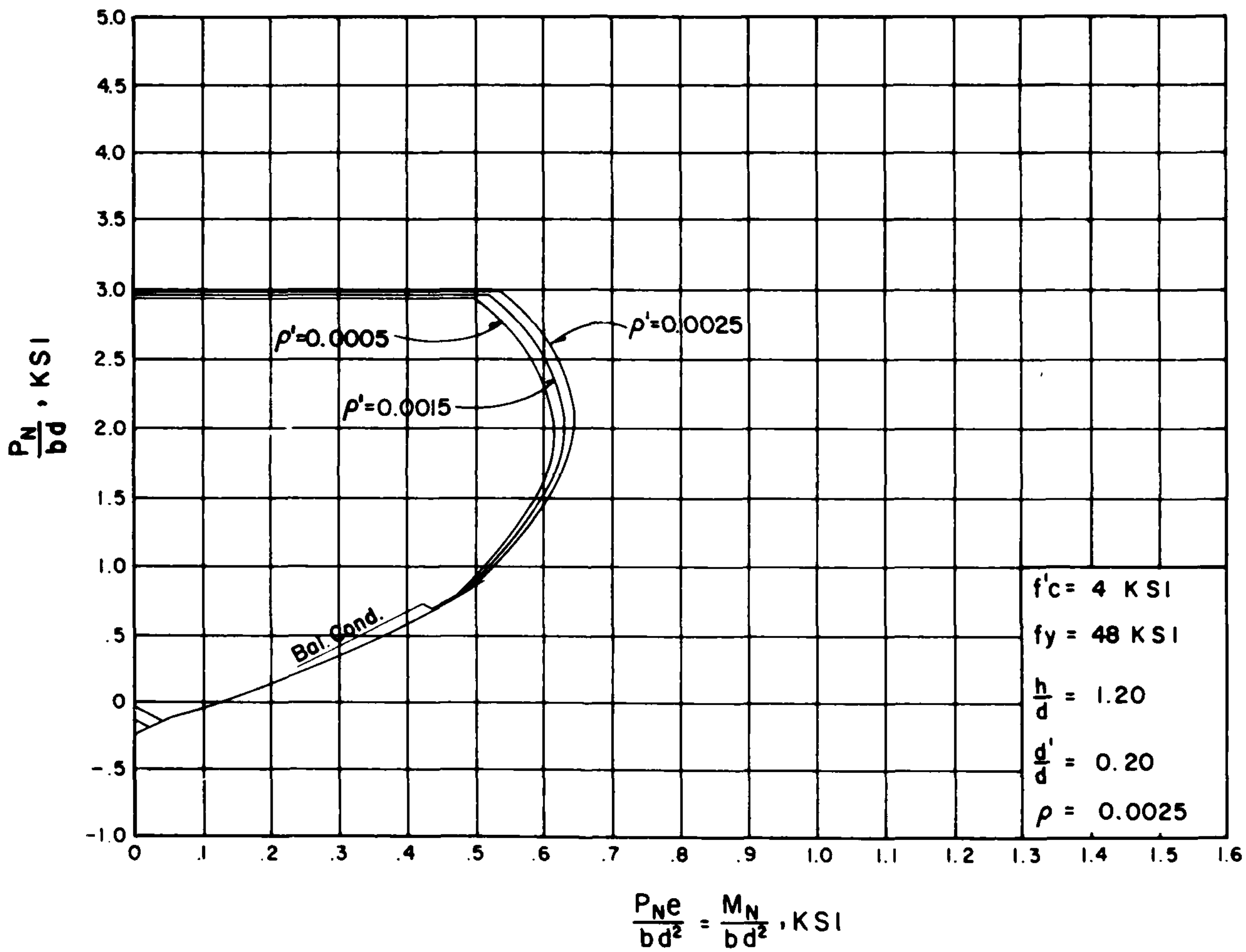


Figure 115. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0025)

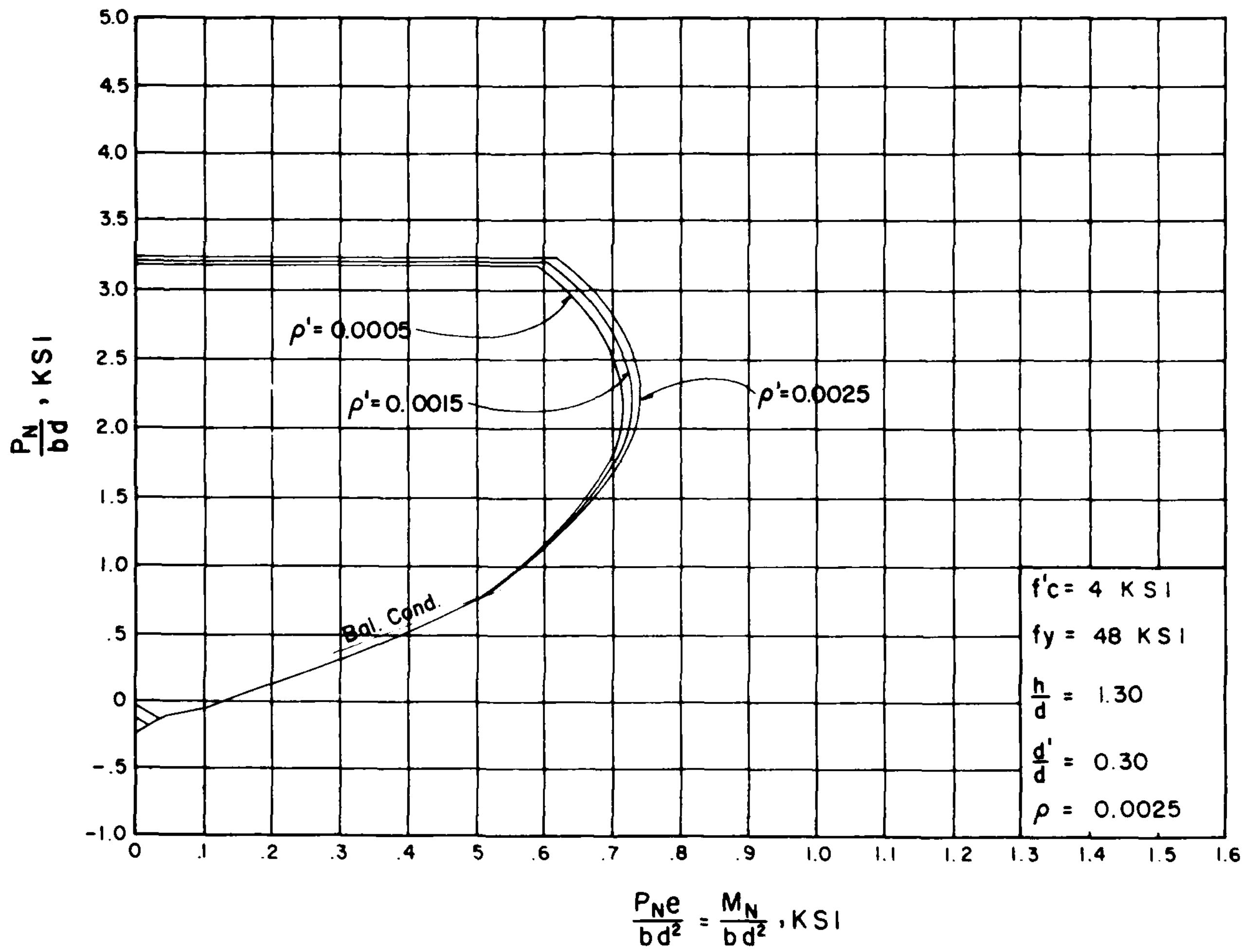


Figure 116. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0025)

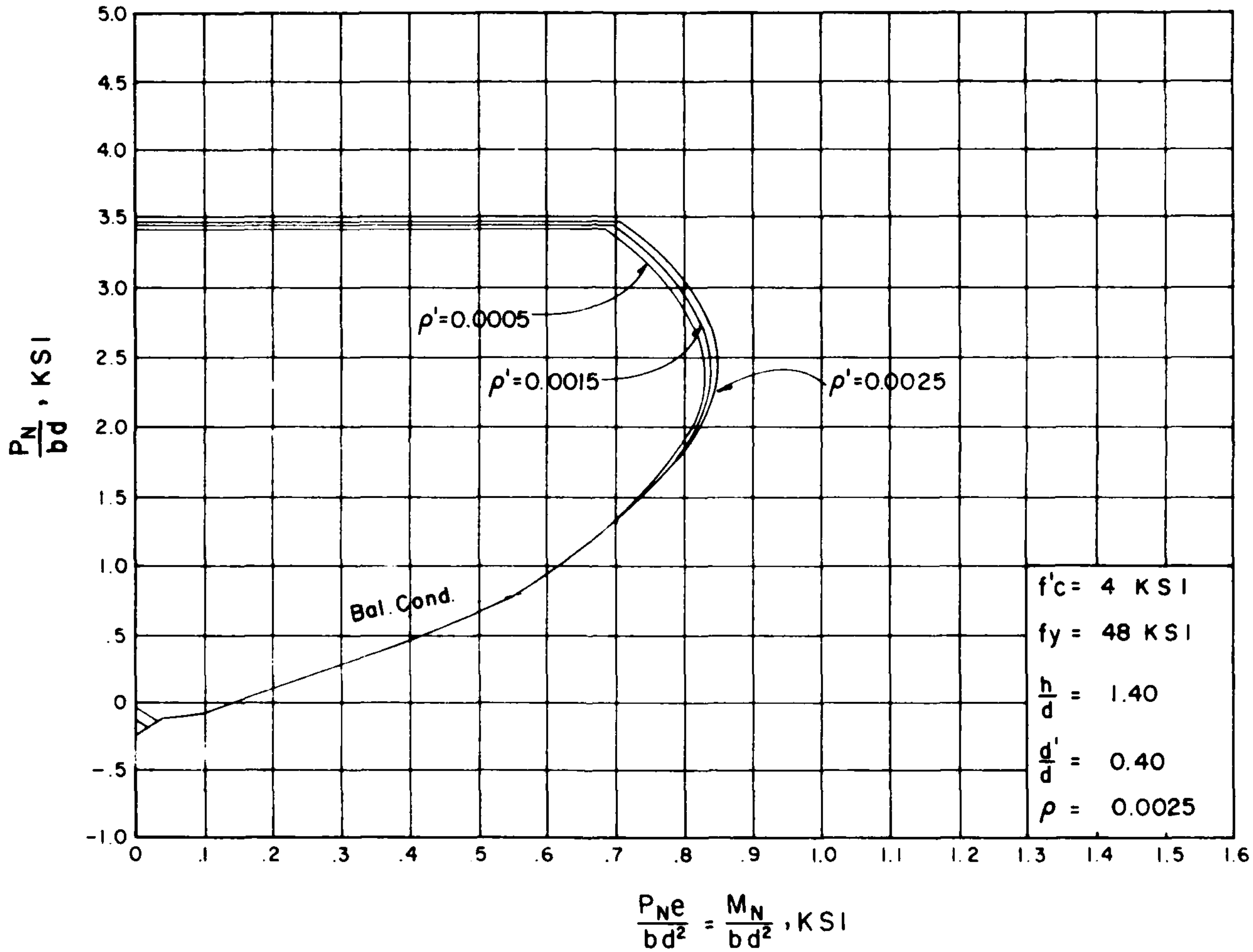


Figure 117. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0025)

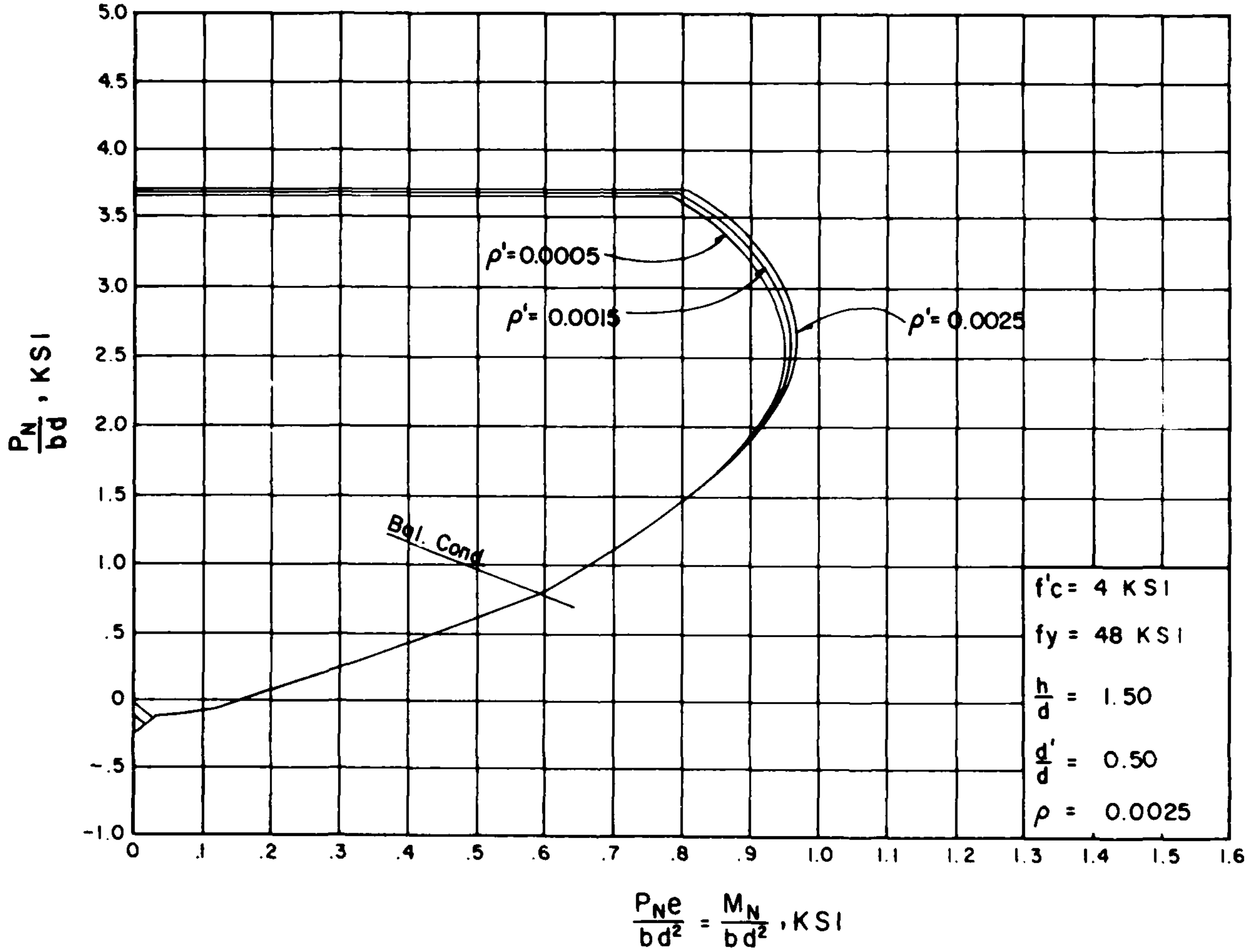


Figure 118. *Load-moment strength interaction diagram for double reinforced members*
(f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0025)

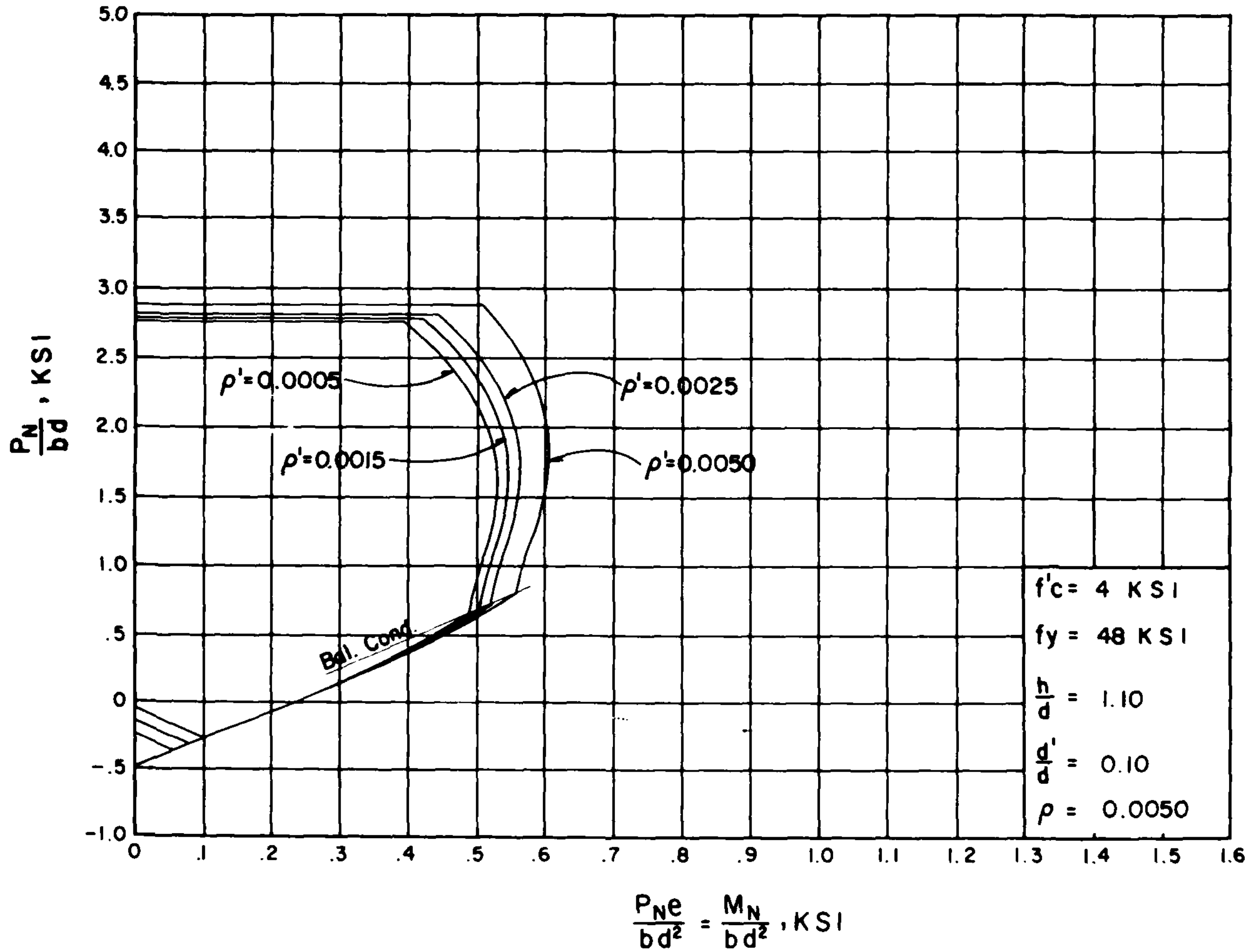


Figure 119. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0050)

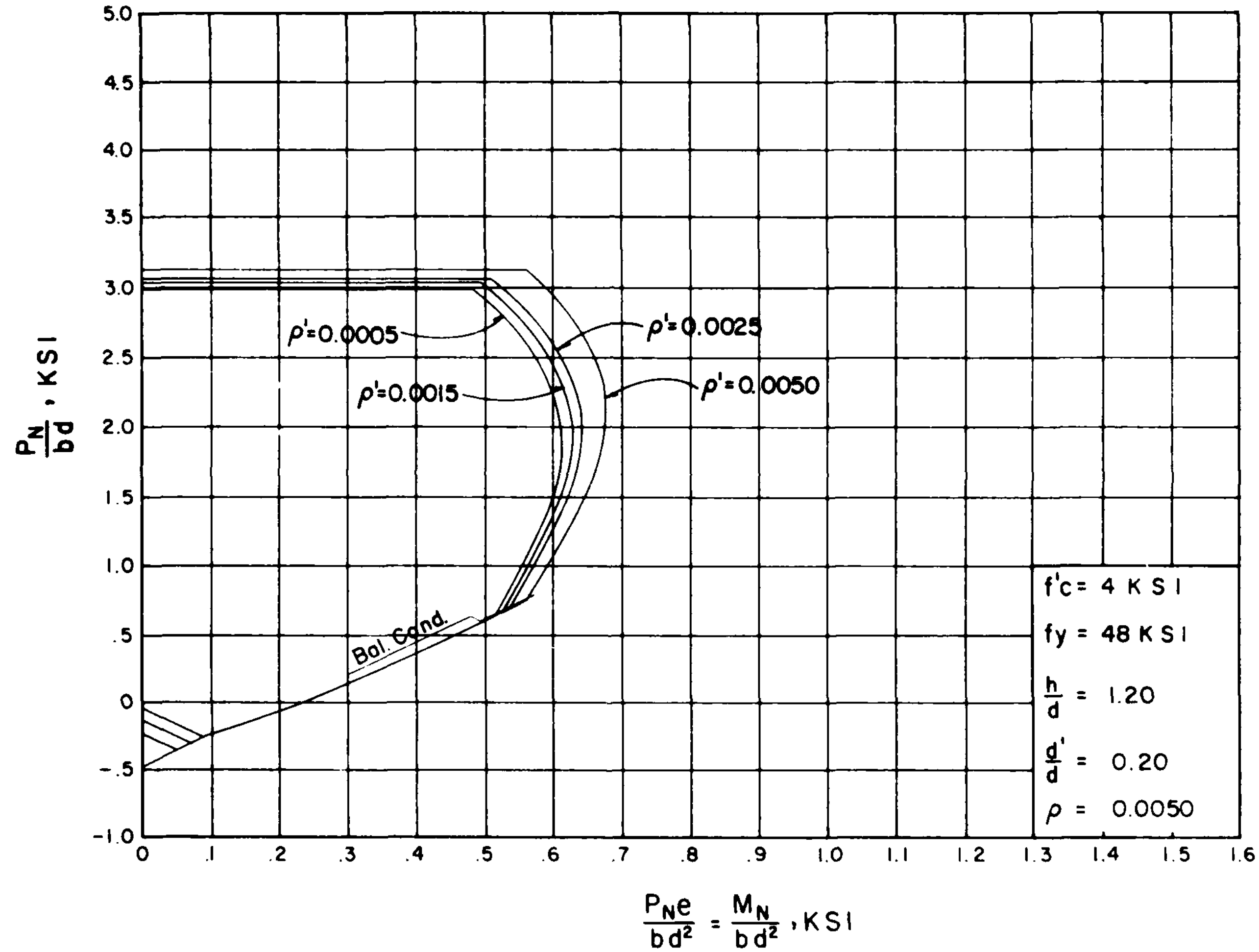


Figure 120. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0050)

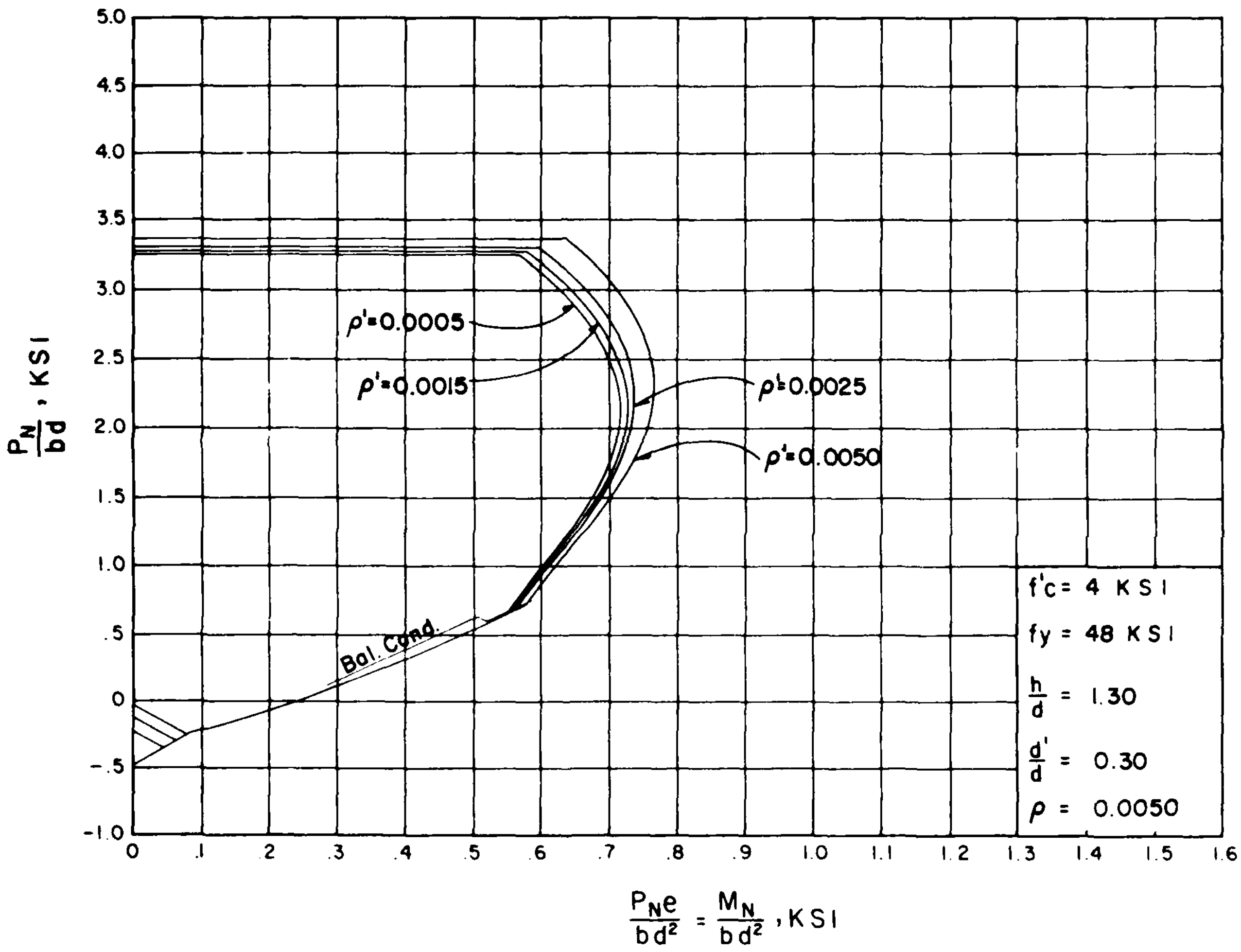


Figure 121. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0050)

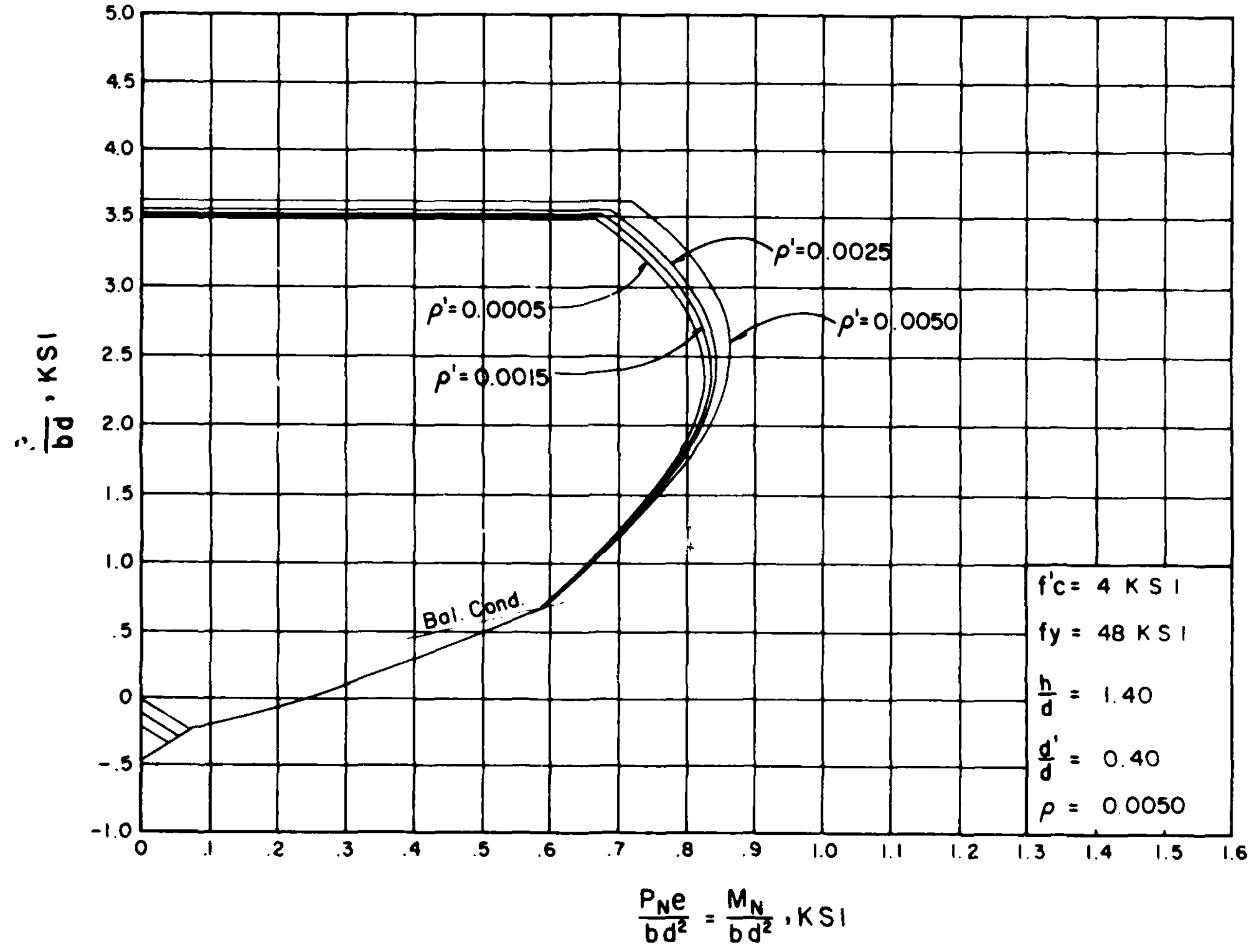


Figure 122. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0050)

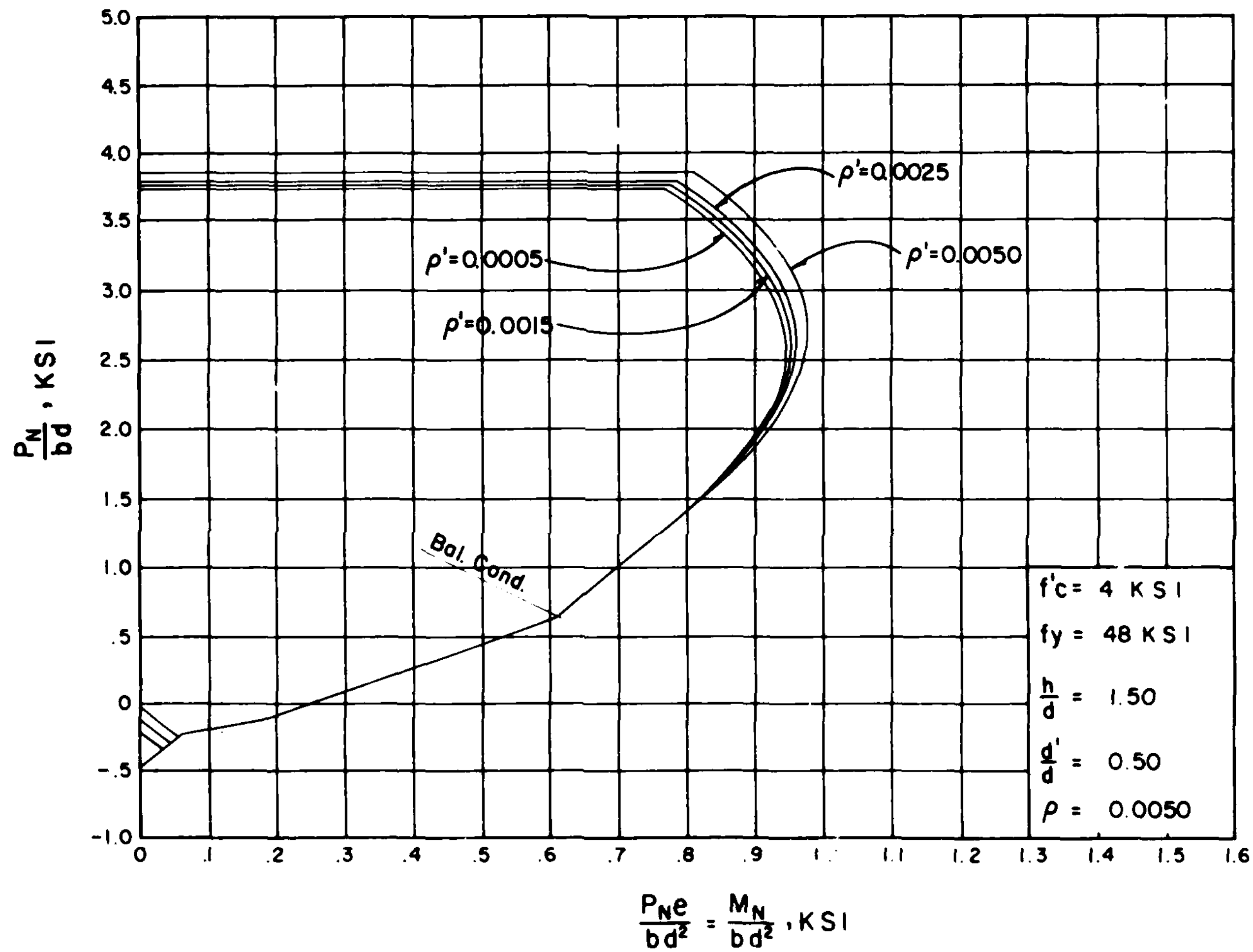


Figure 123. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0050)

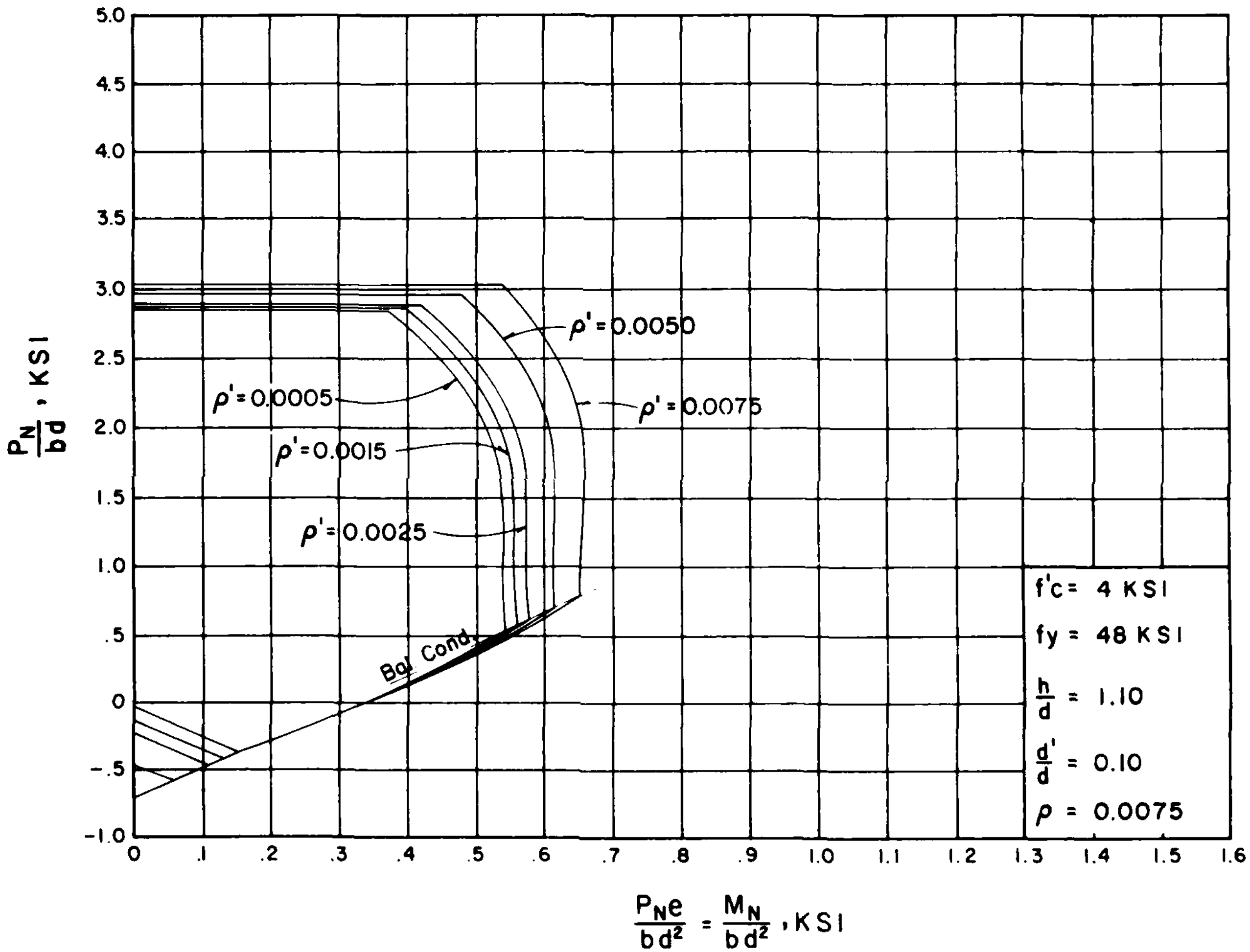


Figure 124. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0075)

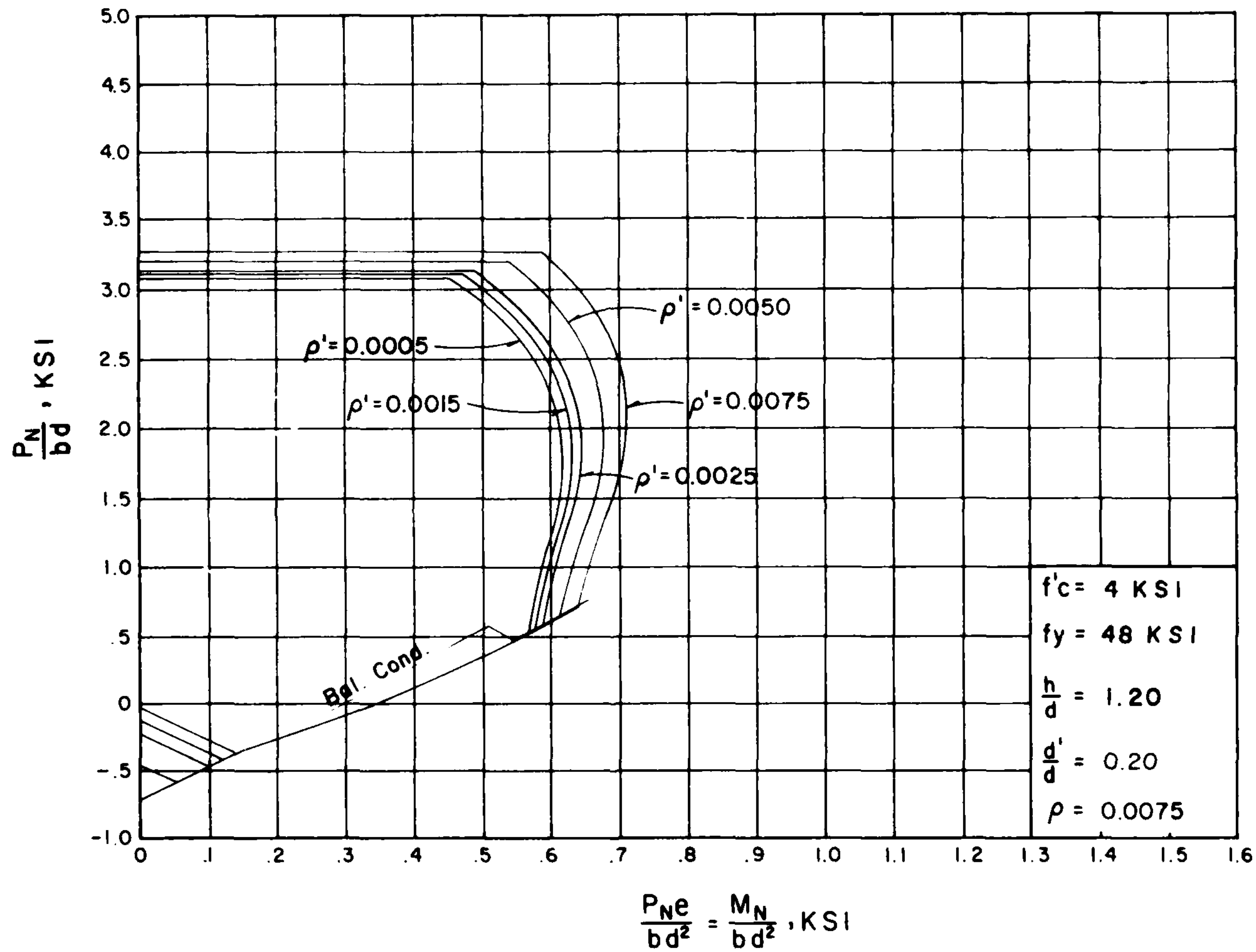


Figure 125. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0075)

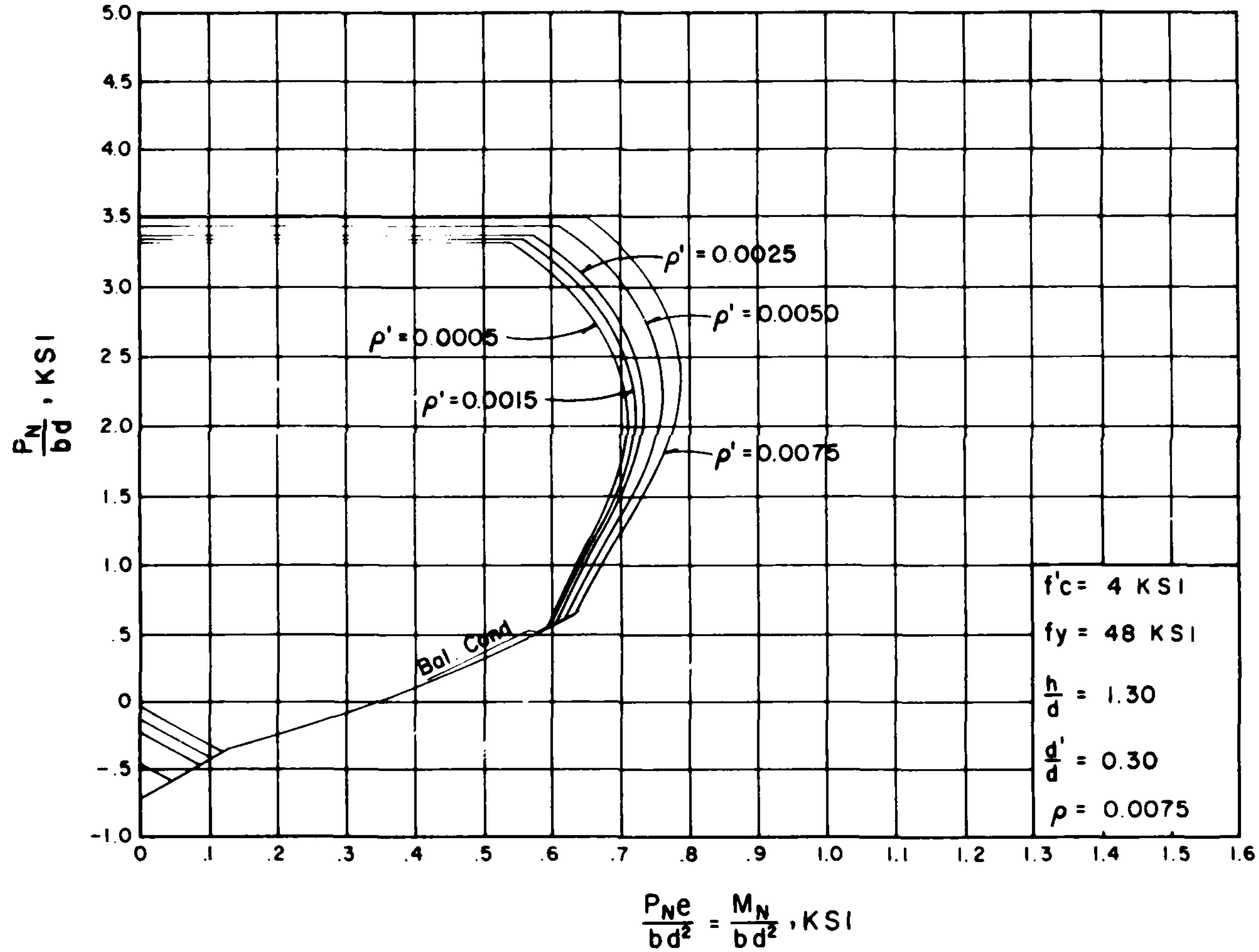


Figure 126. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0075)

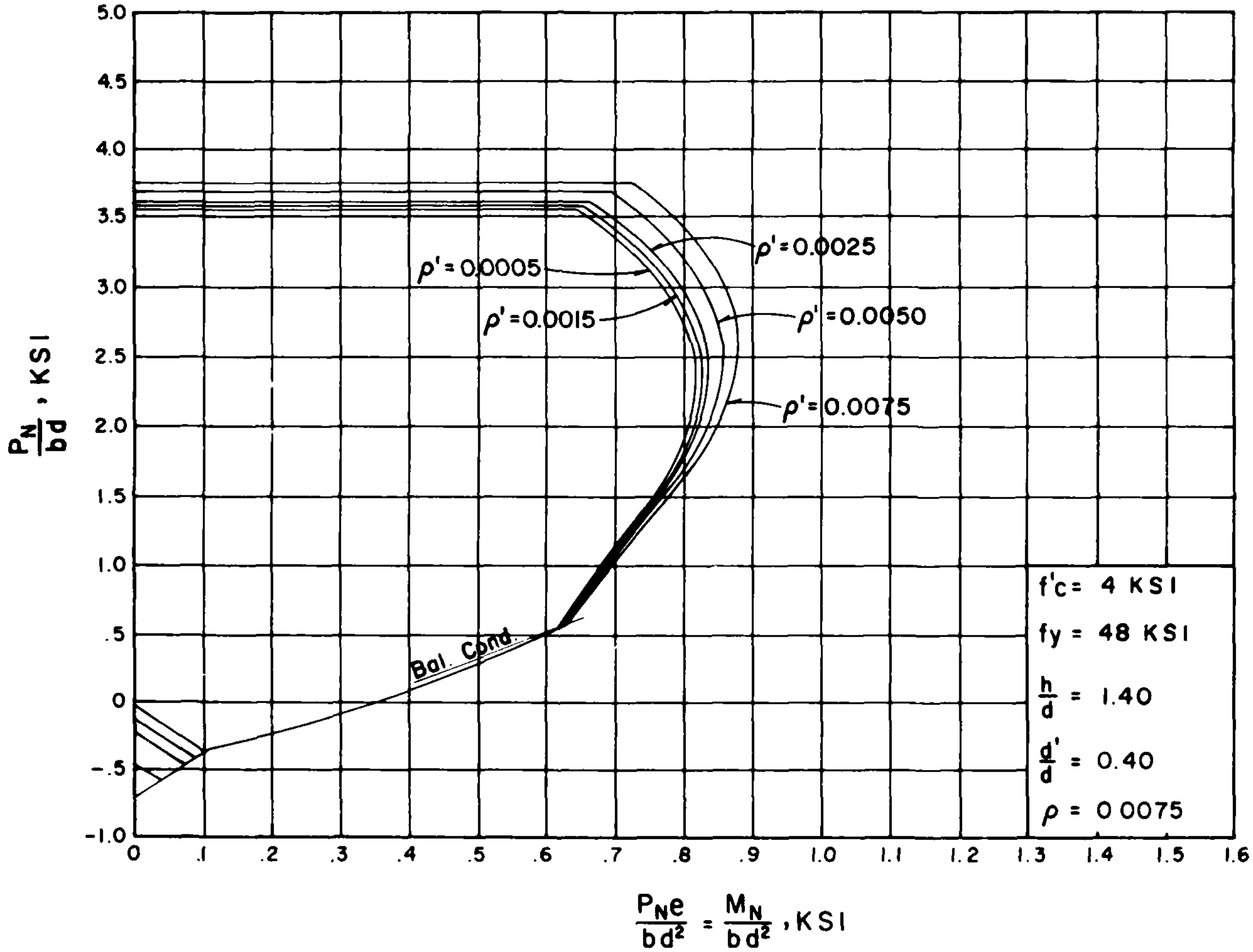


Figure 127. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0075)

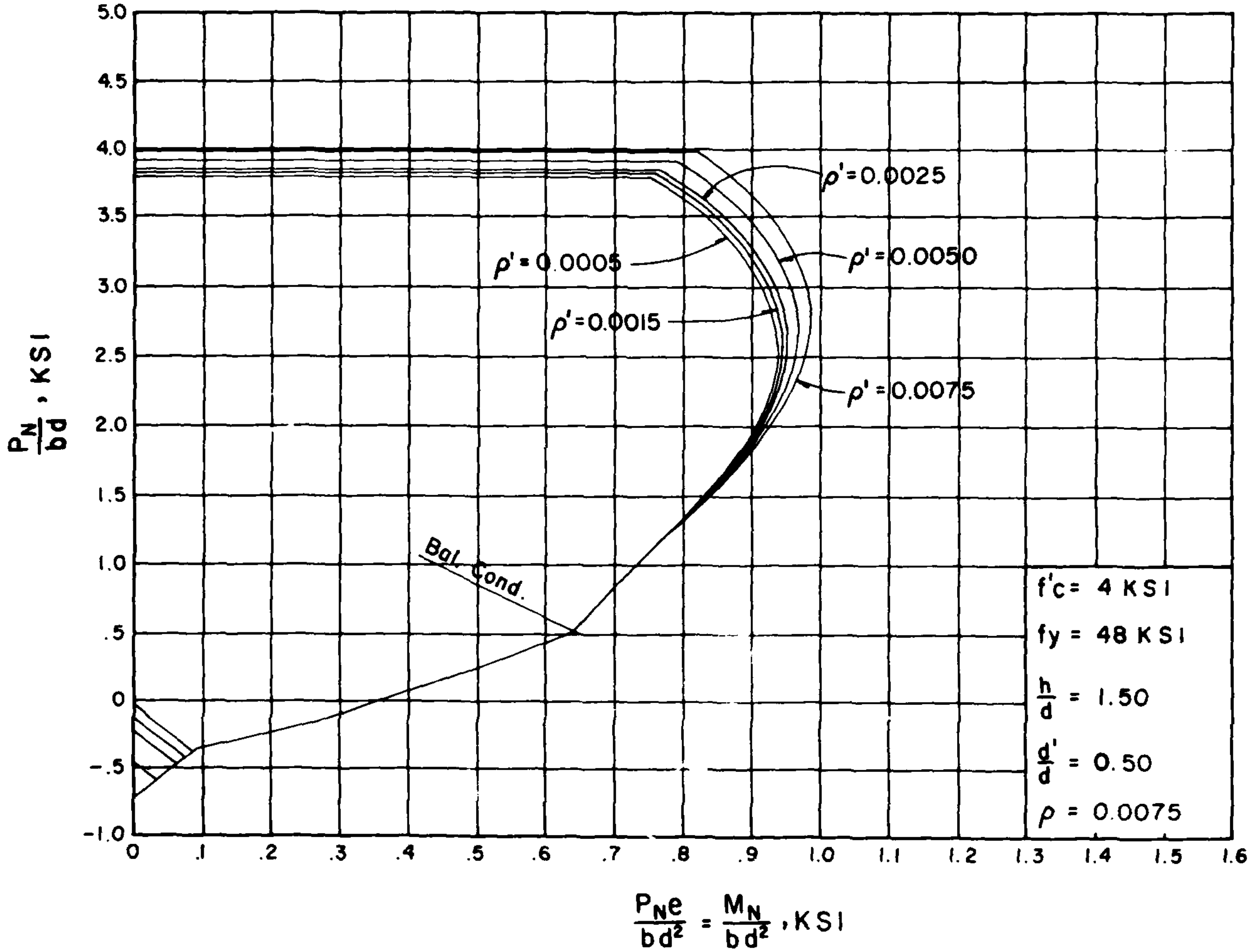


Figure 128. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0075)

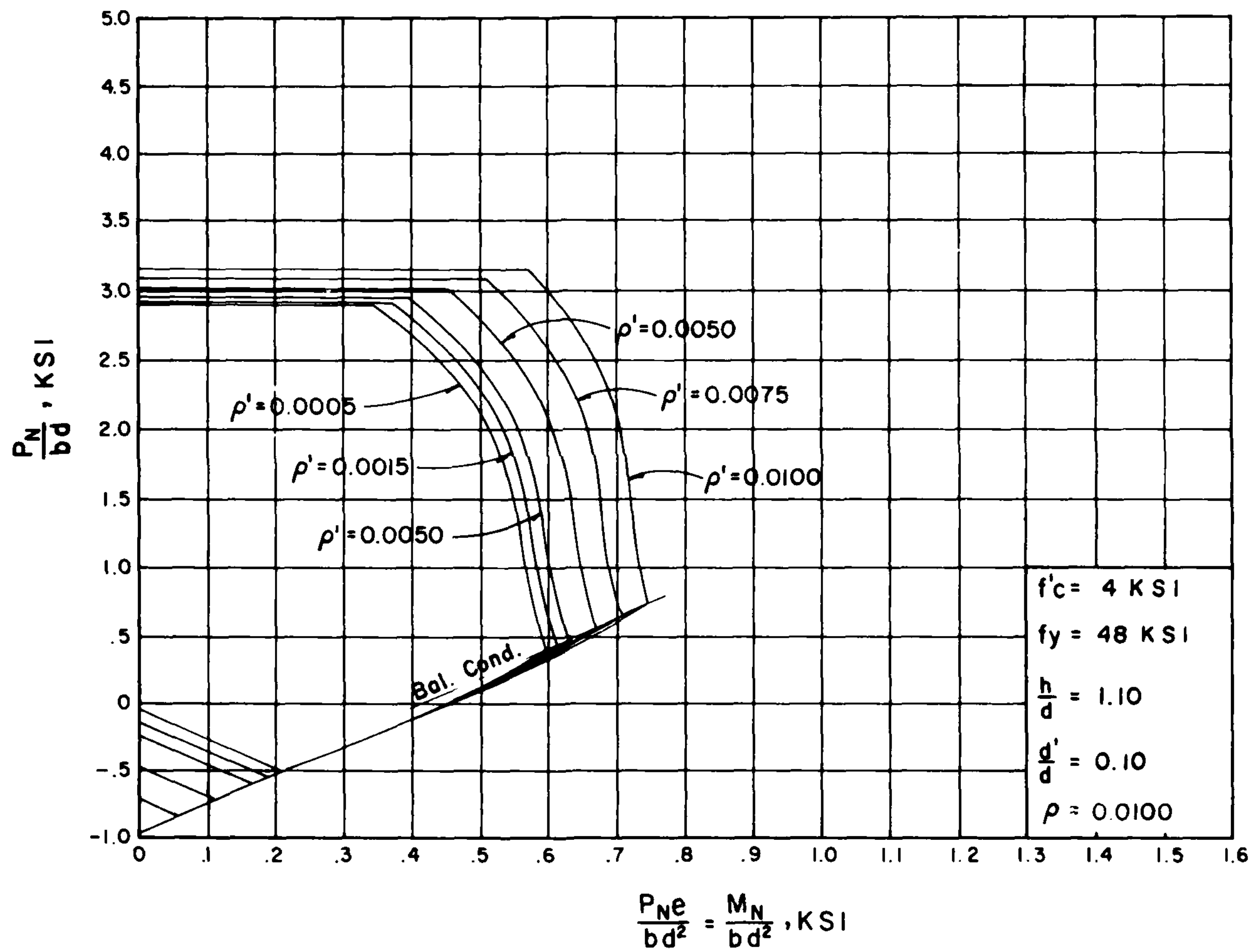


Figure 129. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0100)

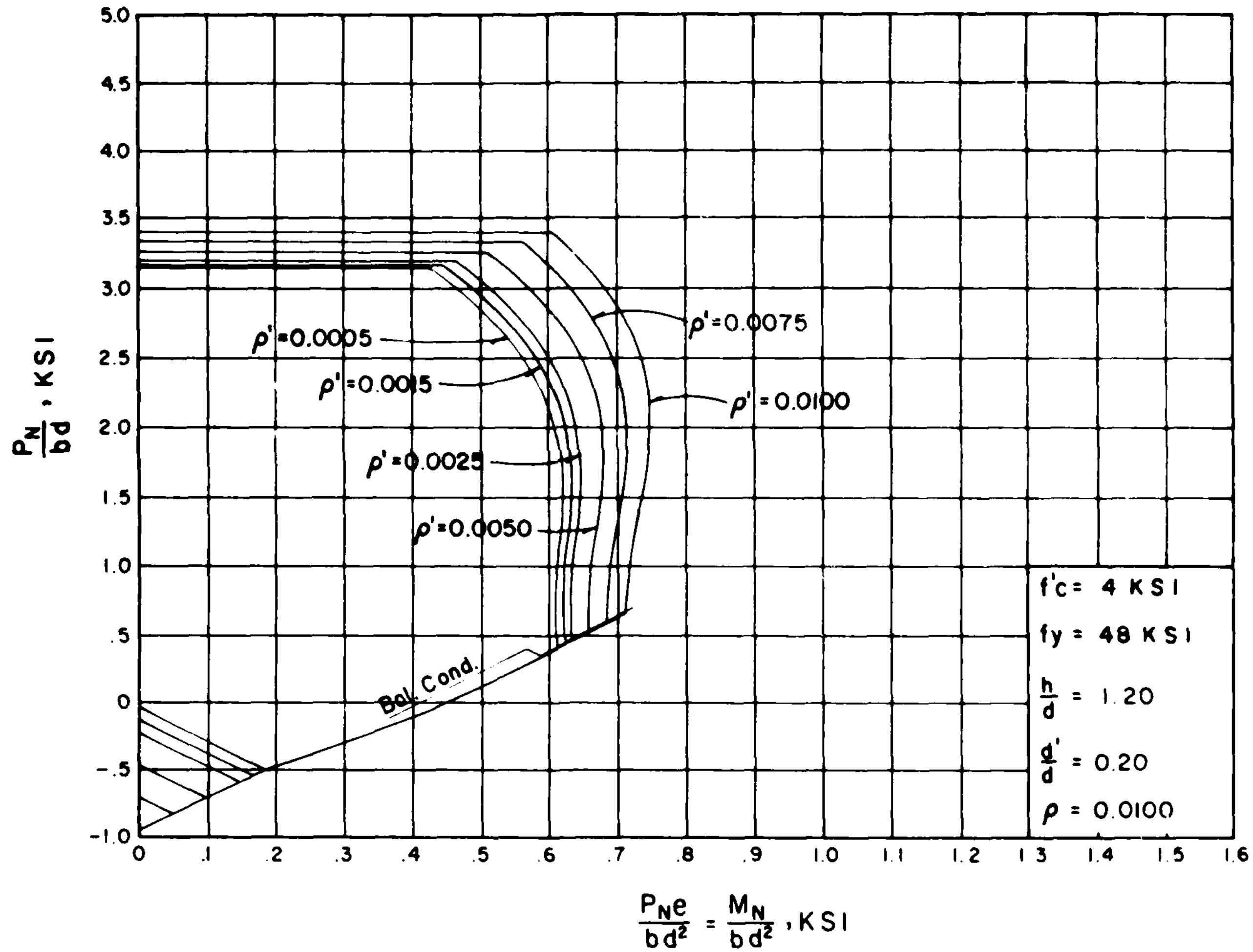


Figure 130. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0100)

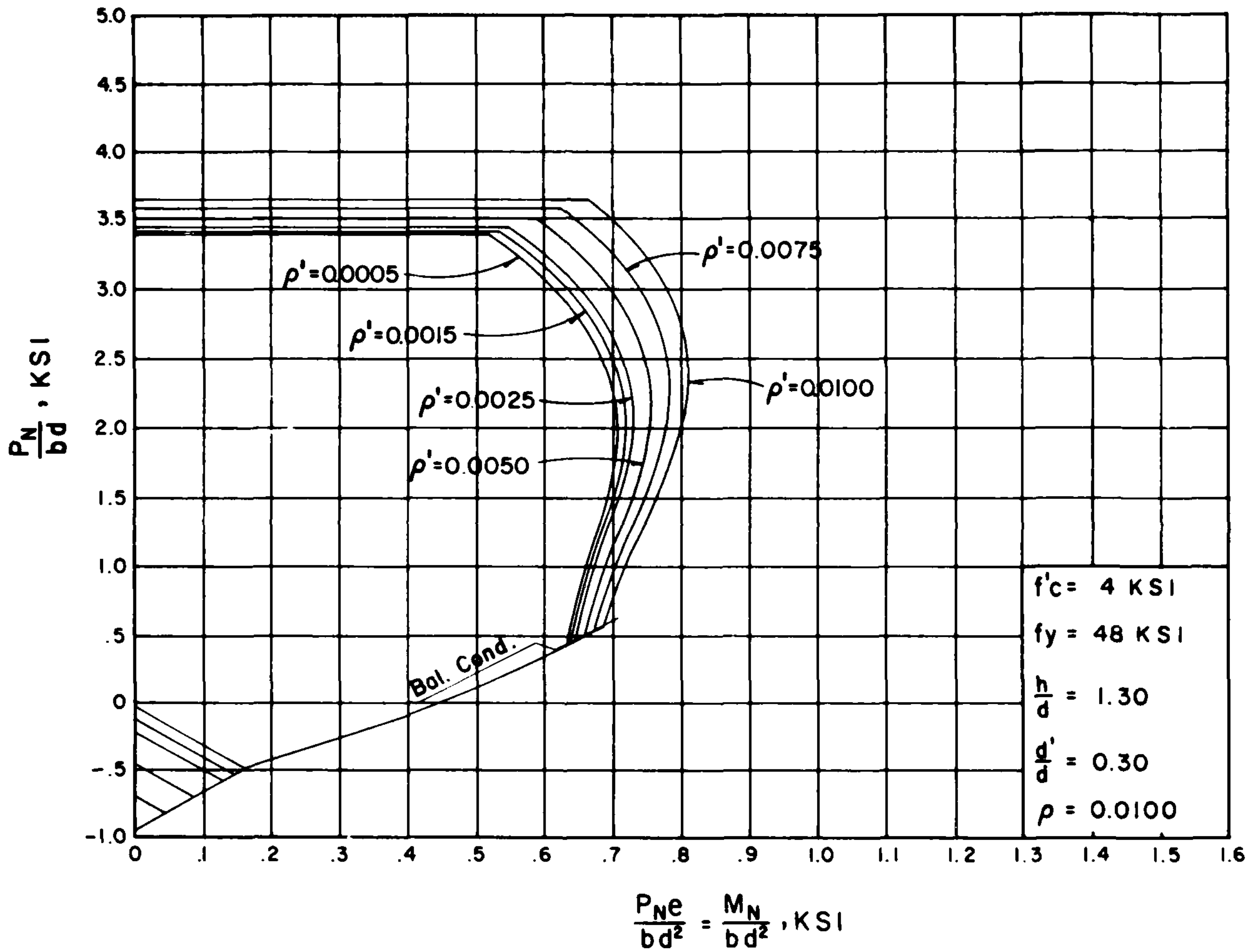


Figure 131. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0100)

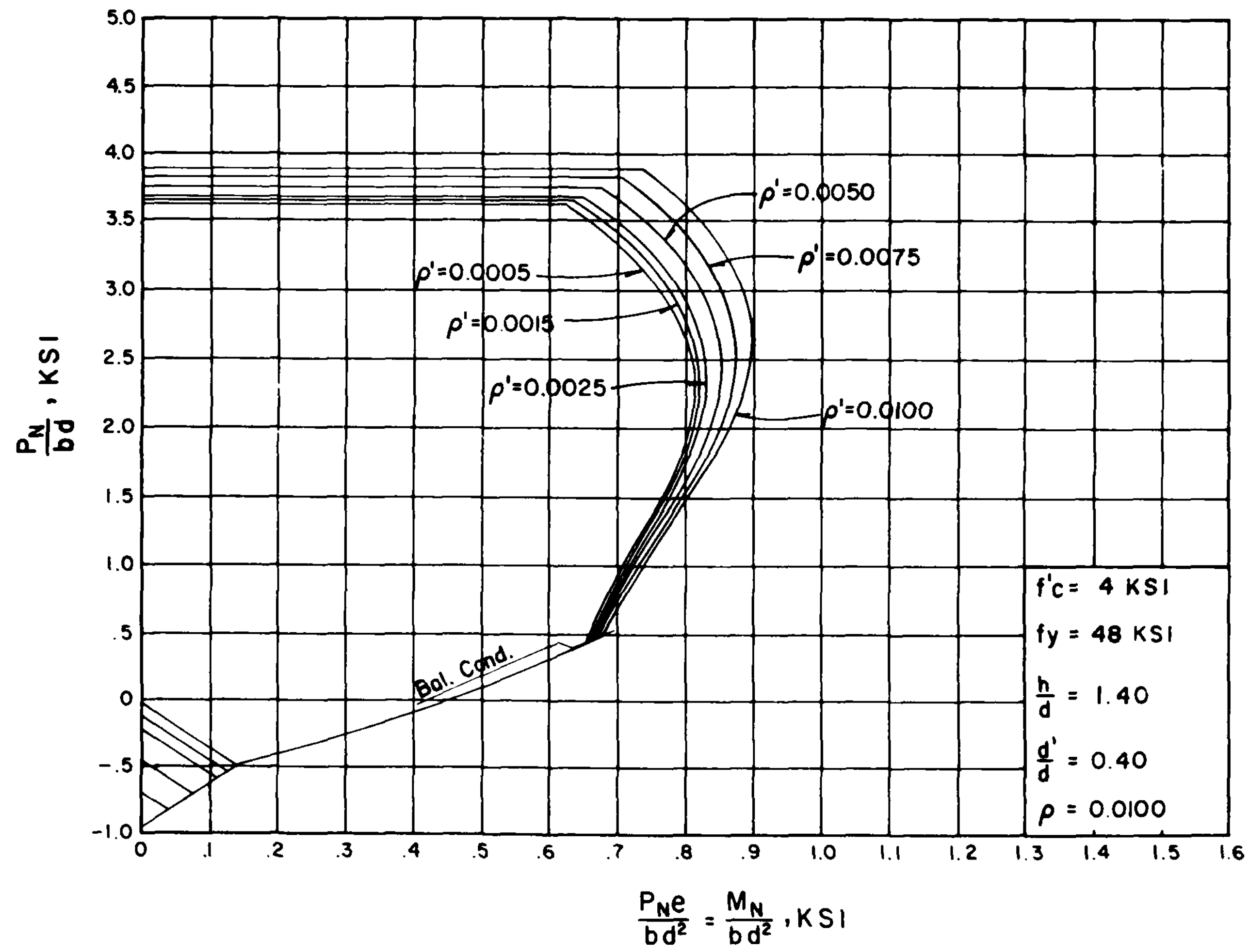


Figure 132. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0100)

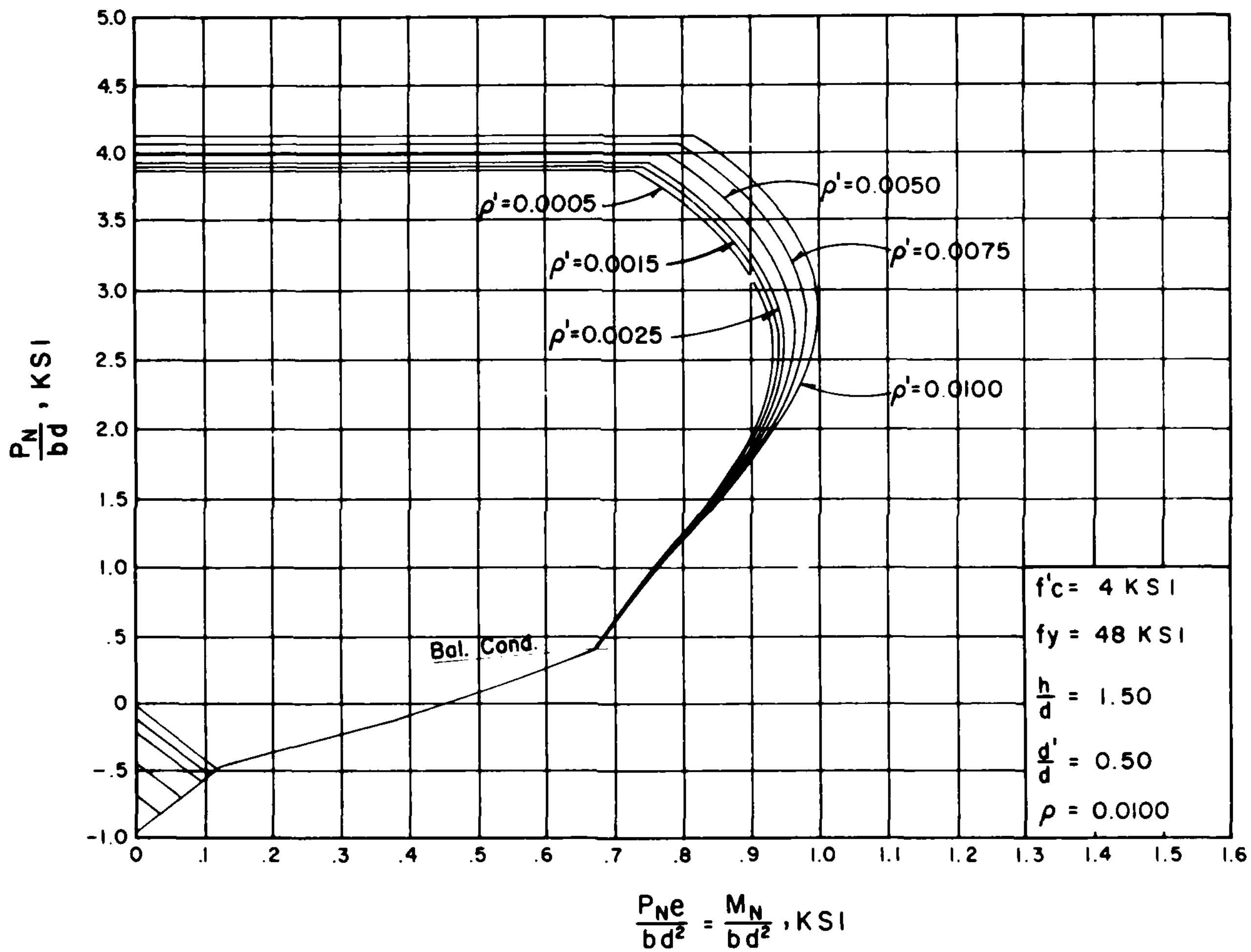


Figure 133. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0100)

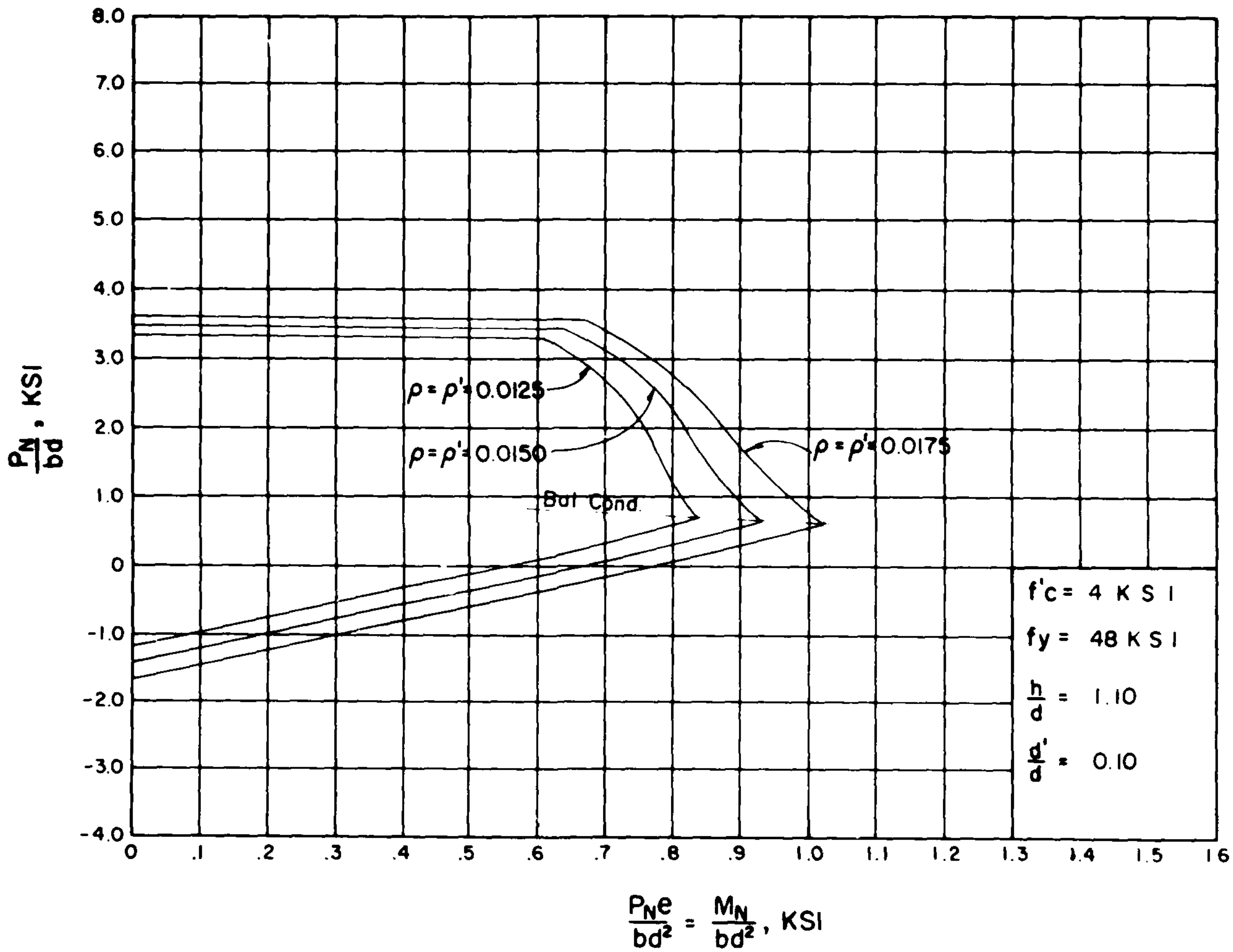


Figure 134. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.10, and d'/d = 0.10)

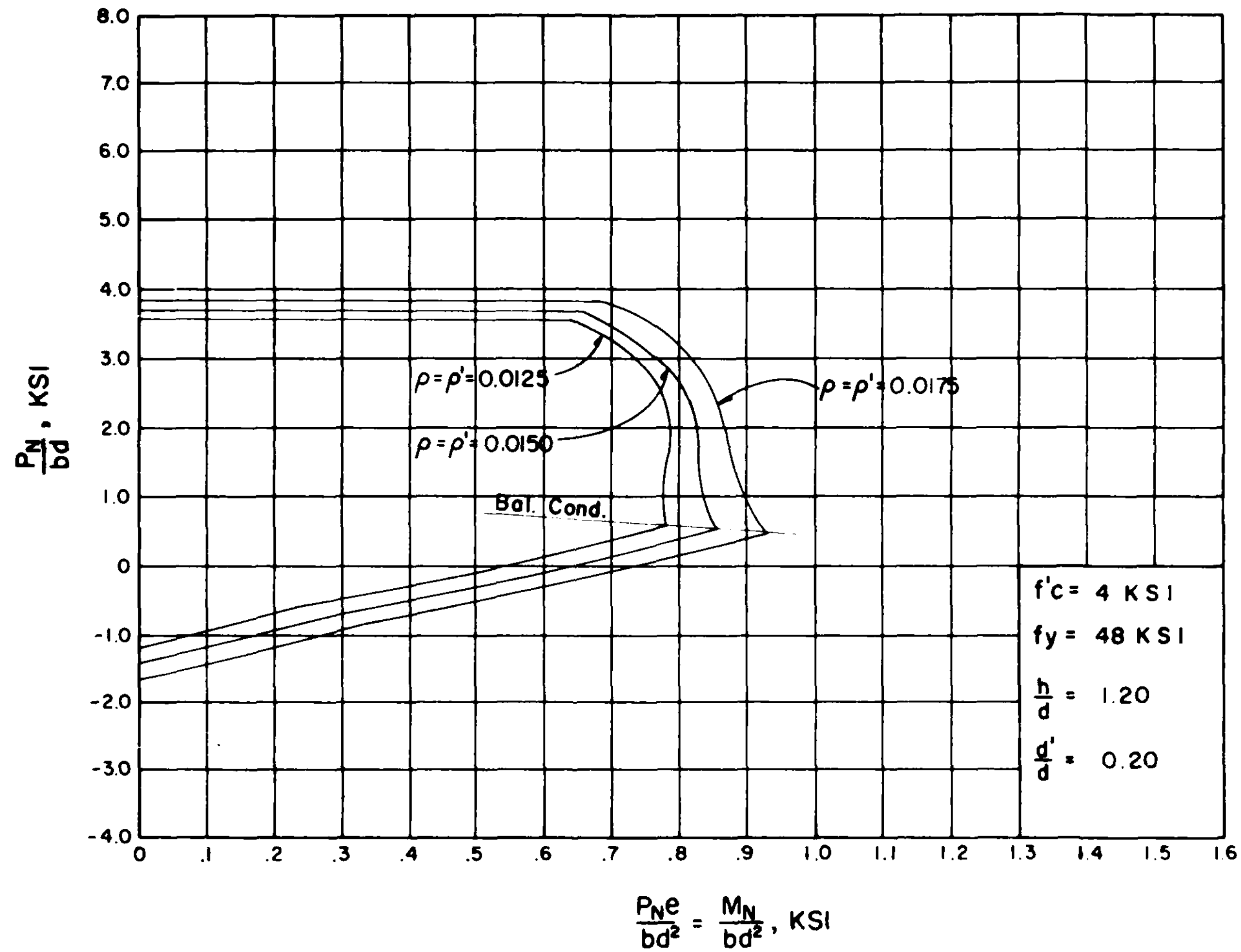


Figure 135. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.20, and d'/d = 0.20)

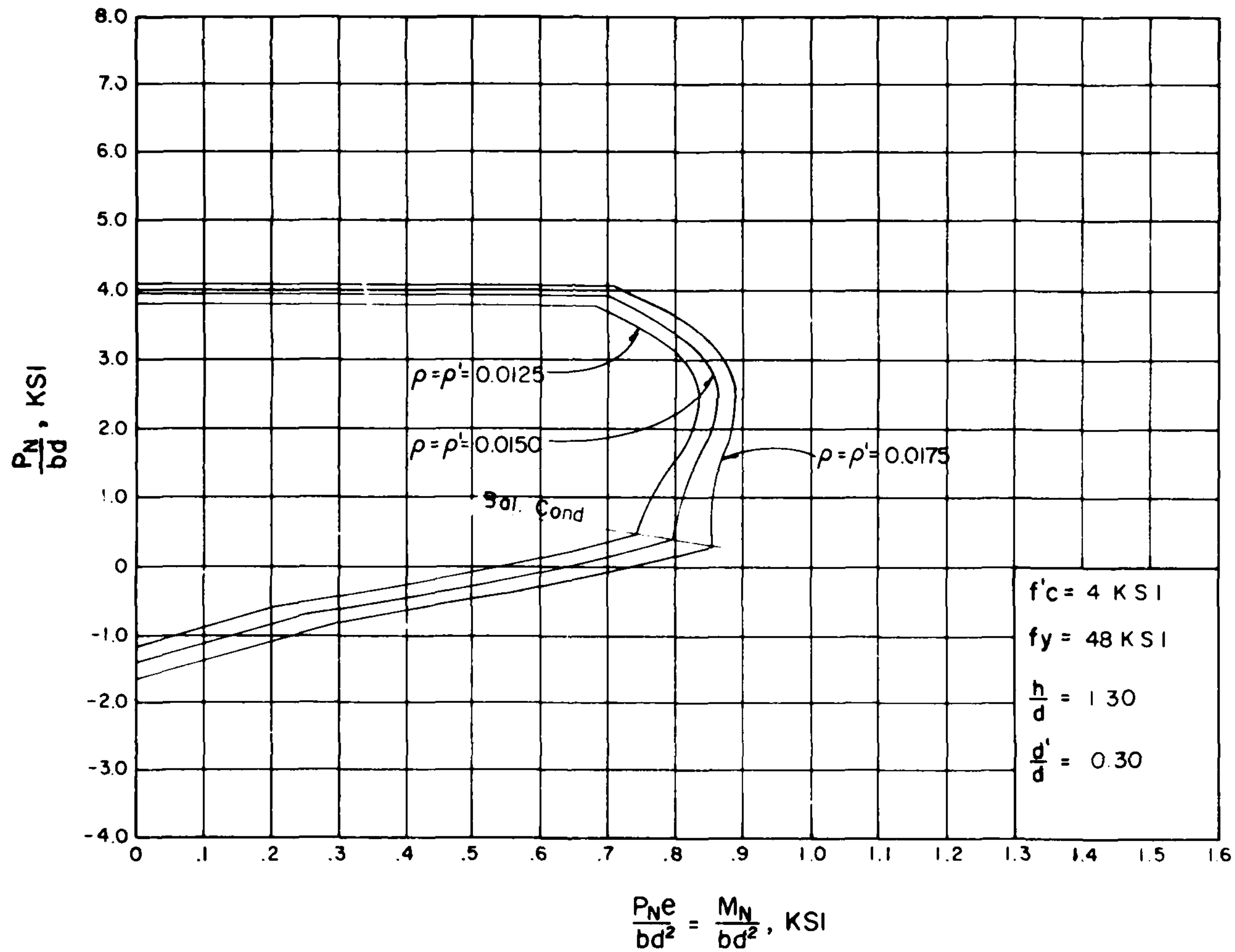


Figure 136. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.30, and d'/d = 0.30)

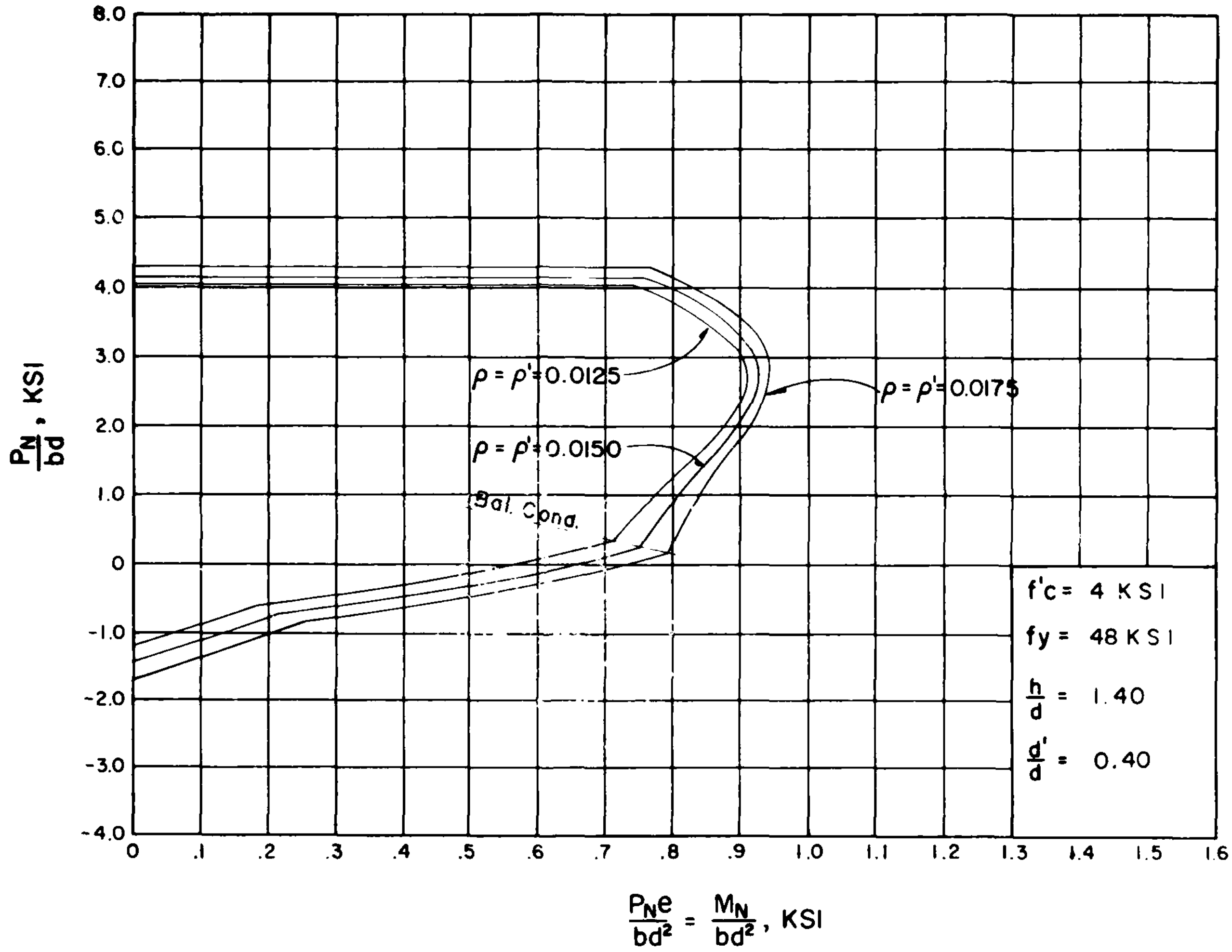


Figure 137. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.40, and d'/d = 0.40)

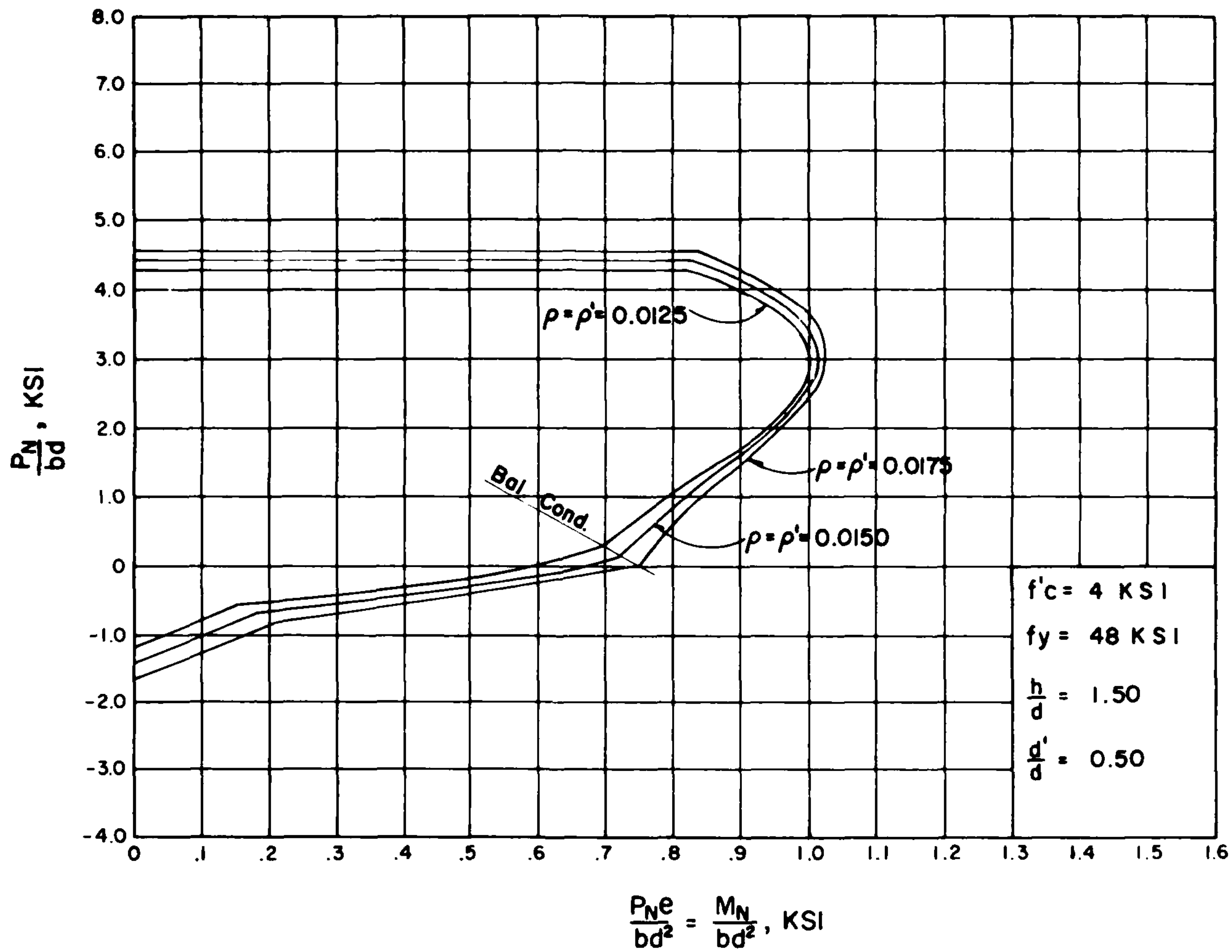


Figure 138. Load-moment strength interaction diagram for double reinforced members (f'_c = 4 ksi, f_y = 48 ksi, h/d = 1.50, and d'/d = 0.50)

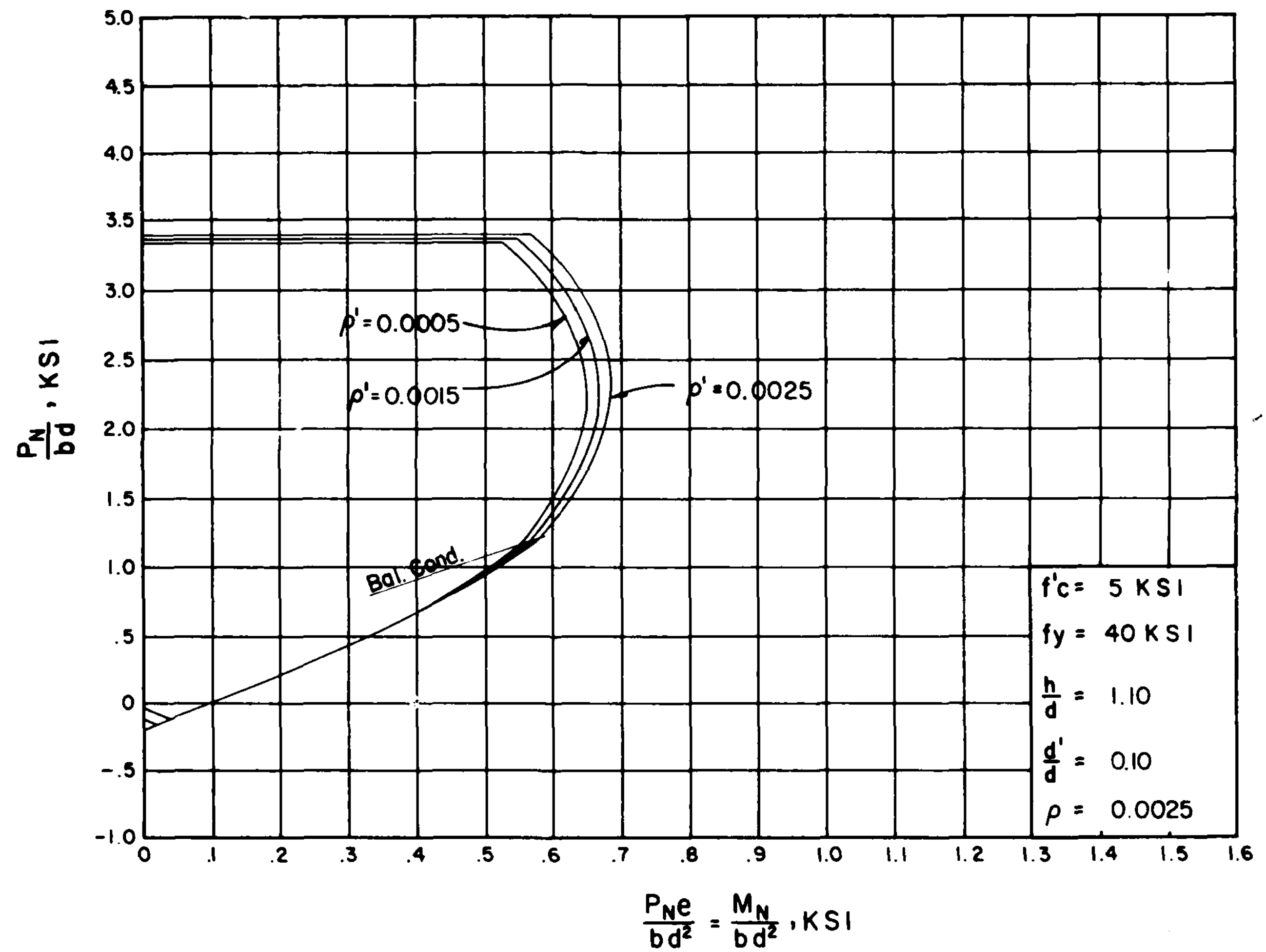


Figure 139. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0025)

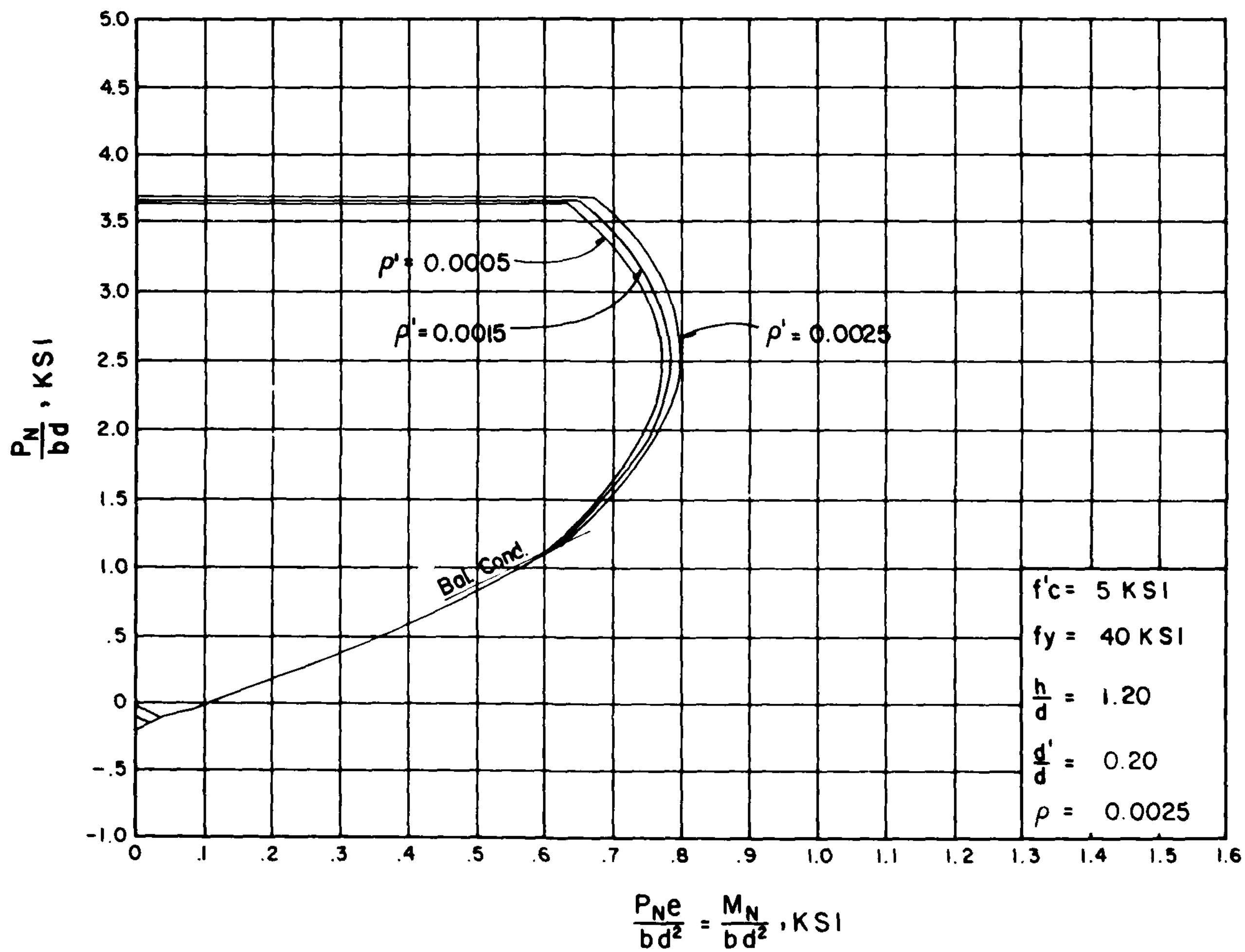


Figure 140. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0025)

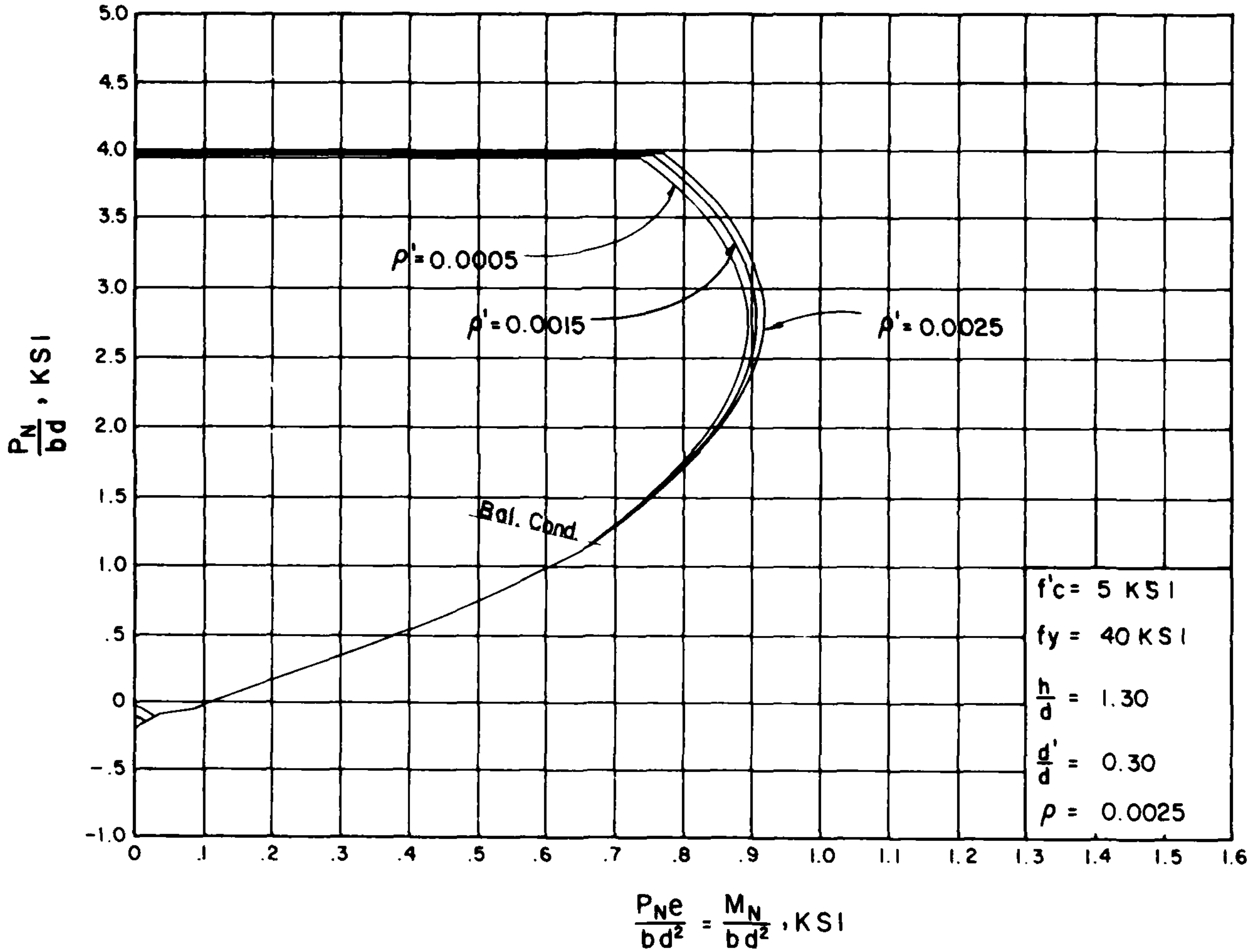


Figure 141. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0025)

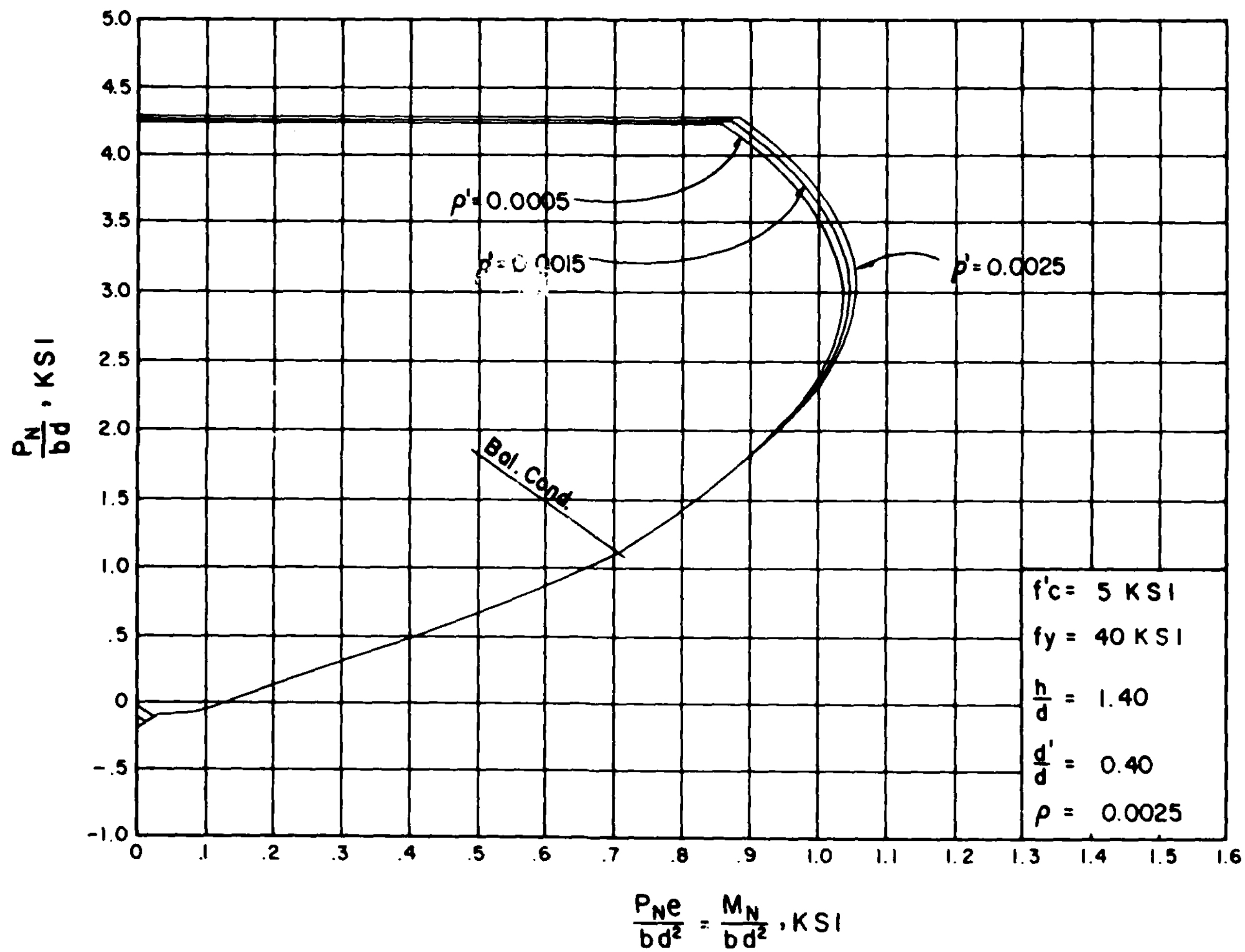


Figure 142. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0025)

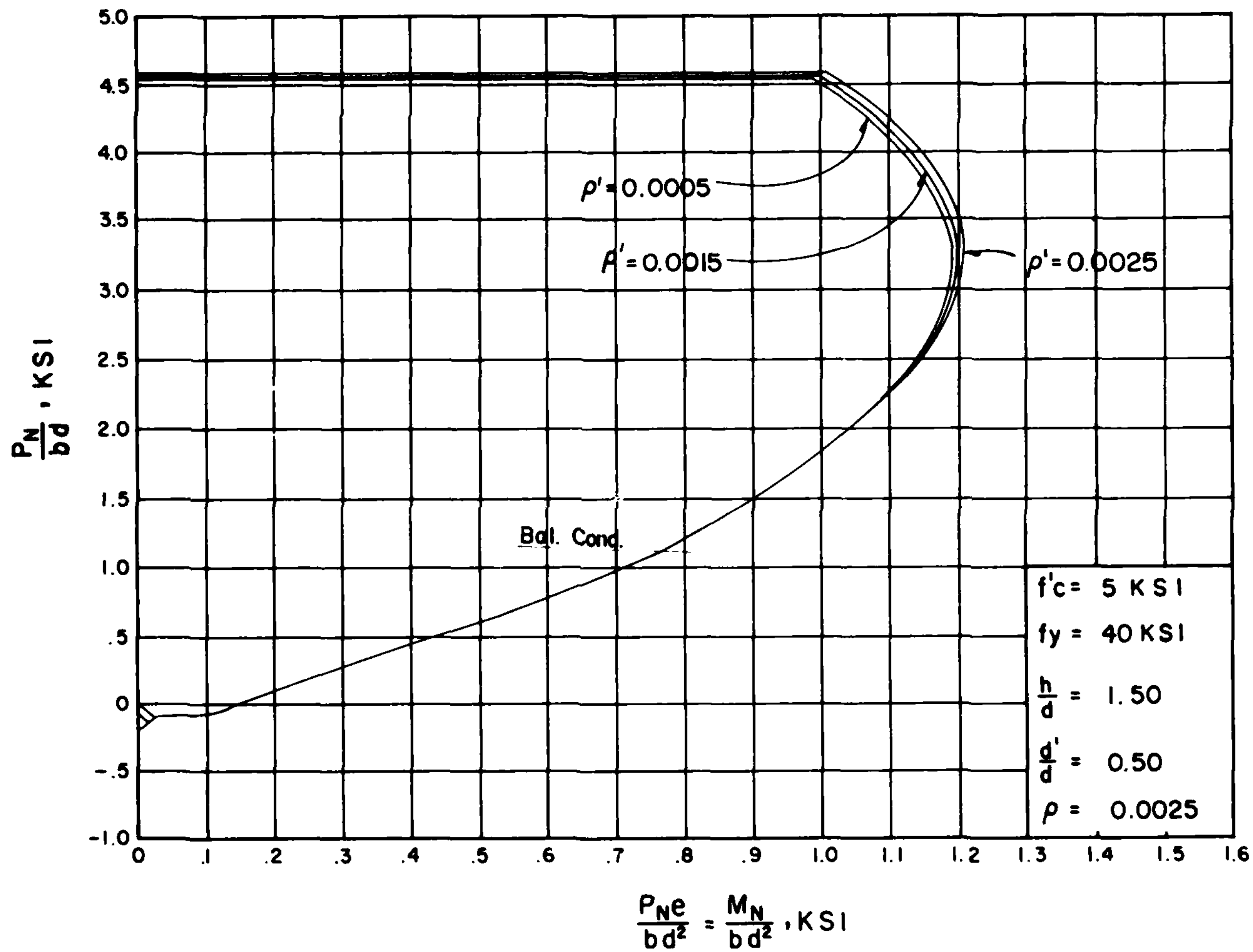


Figure 143. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0025)

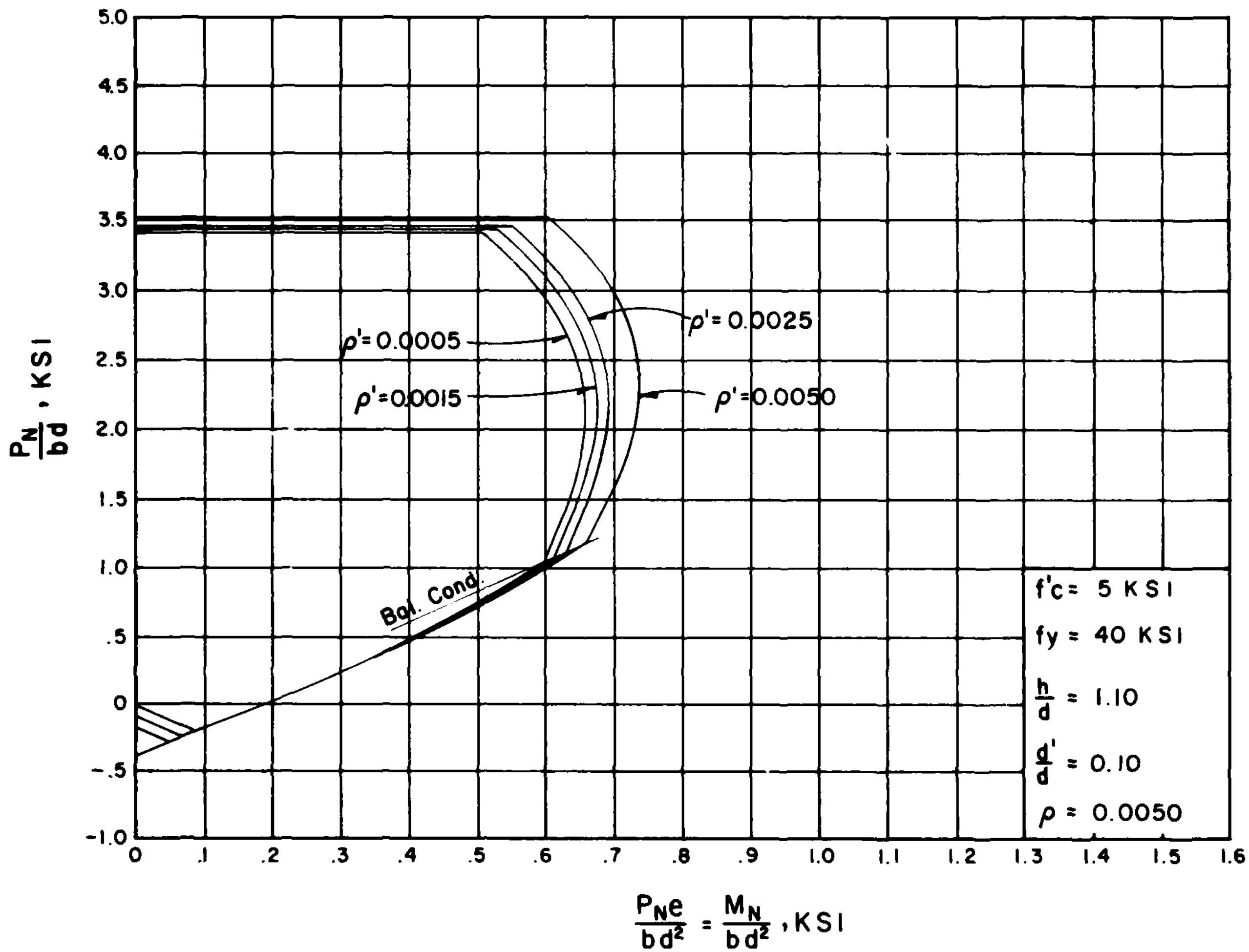


Figure 144. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0050)

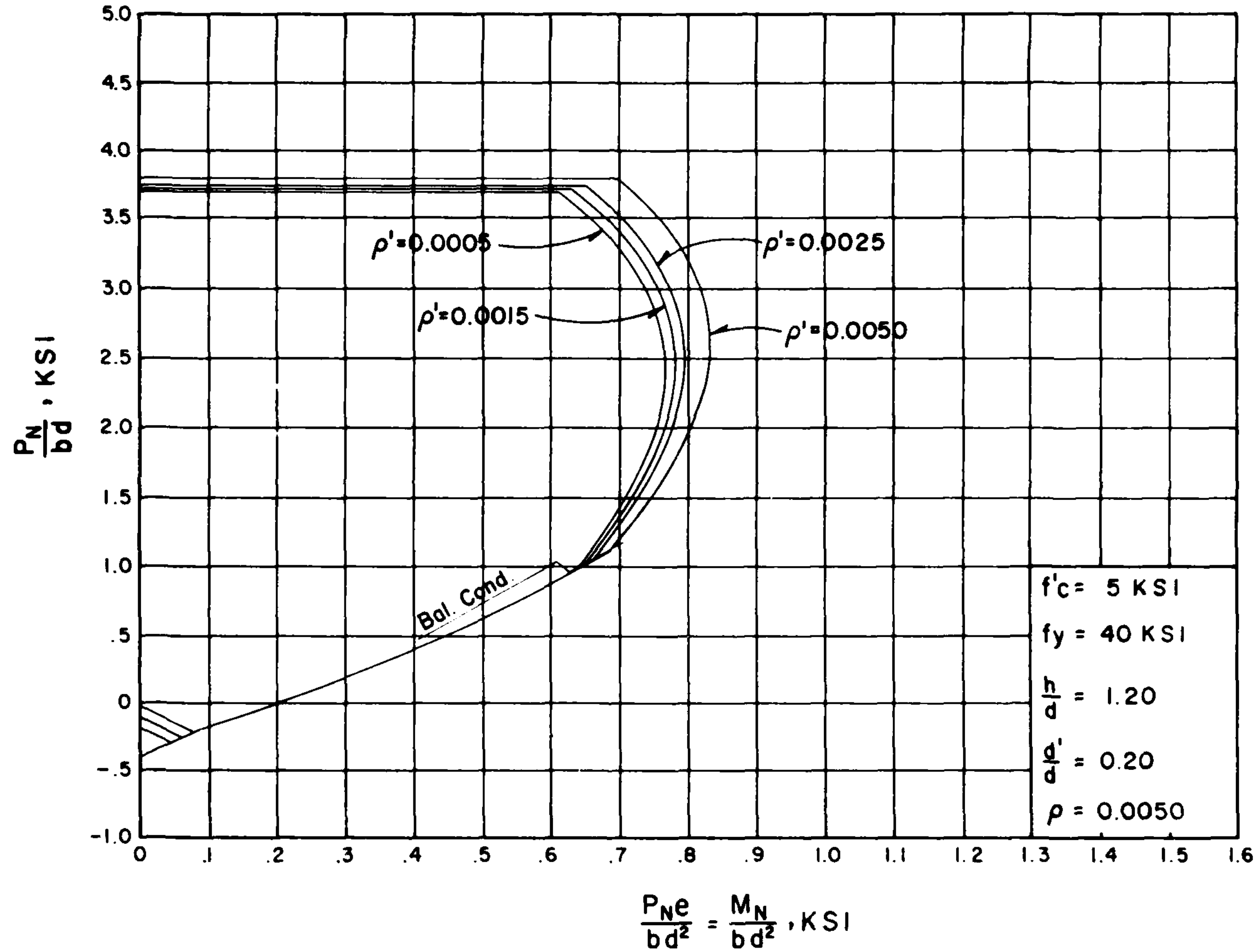


Figure 145. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0050)

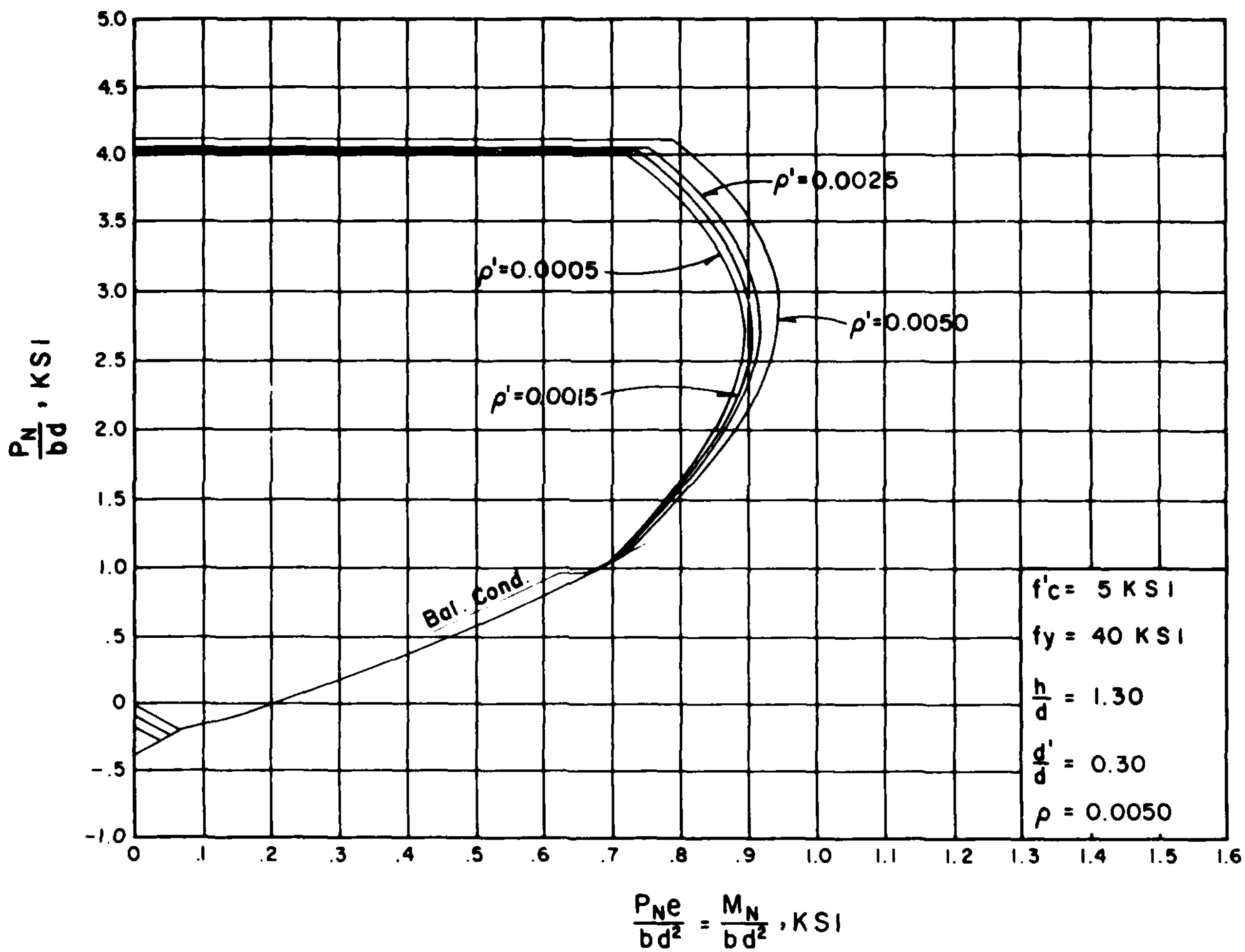


Figure 146. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0050)

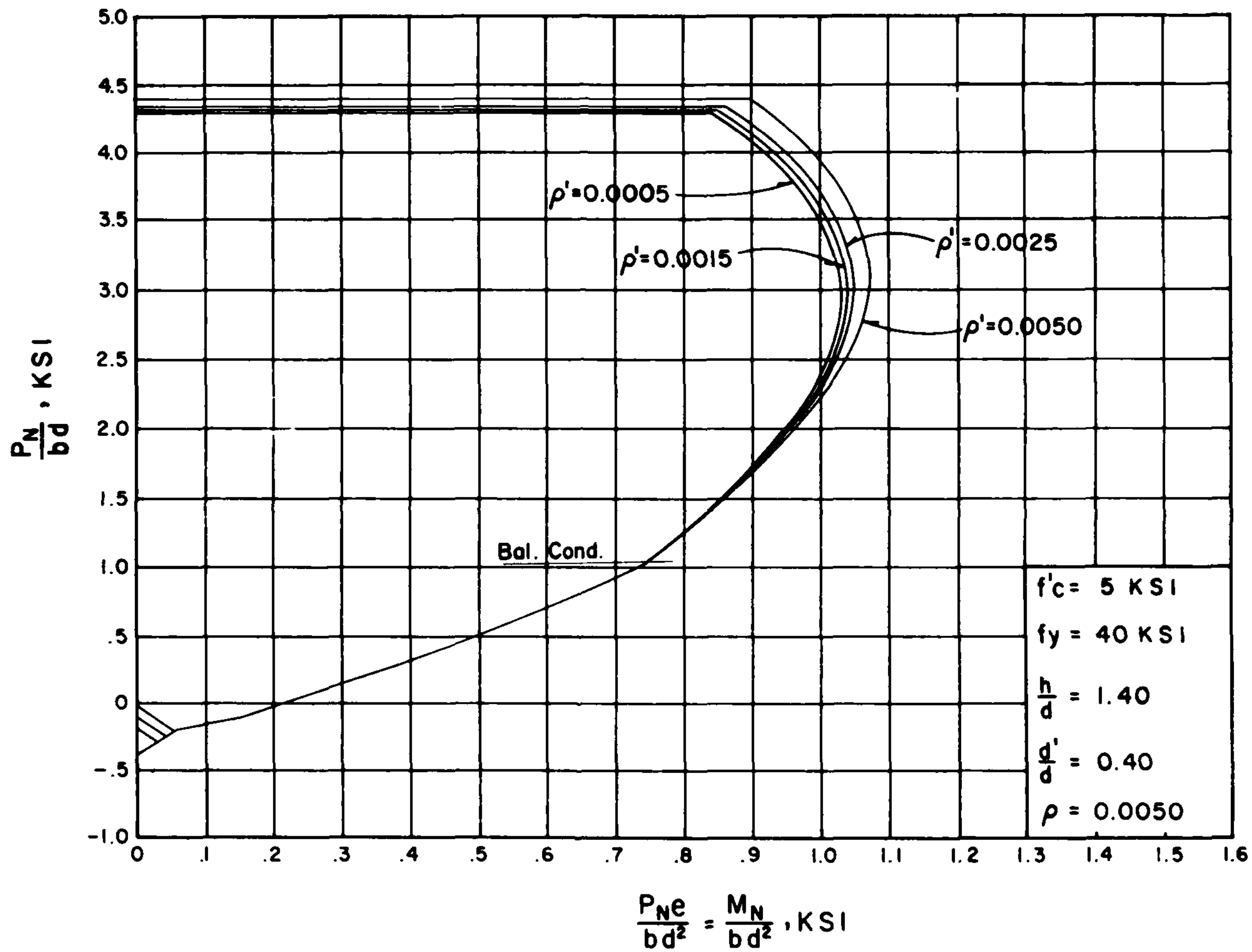


Figure 147. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0050)

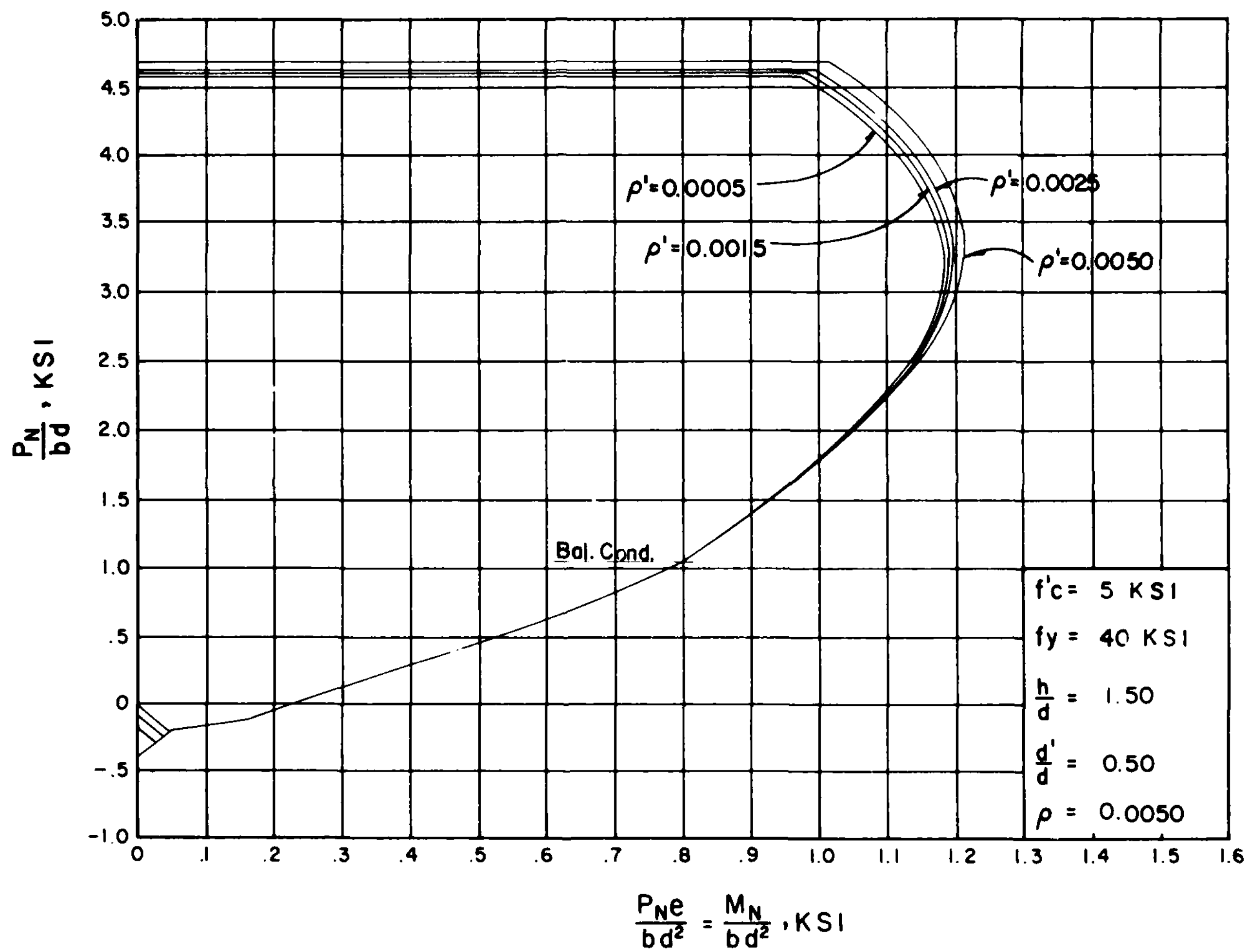


Figure 148. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0050)

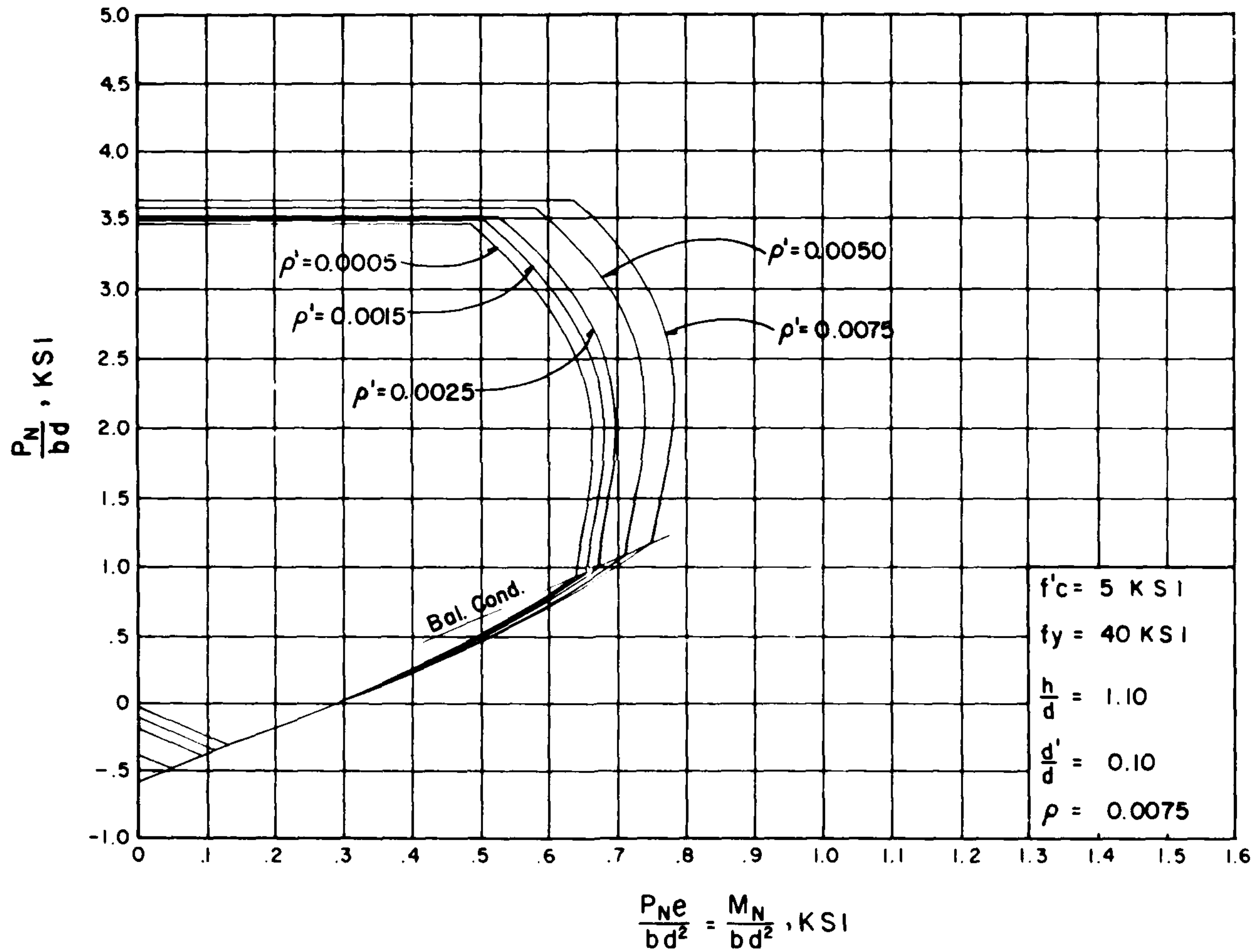


Figure 149. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0075)

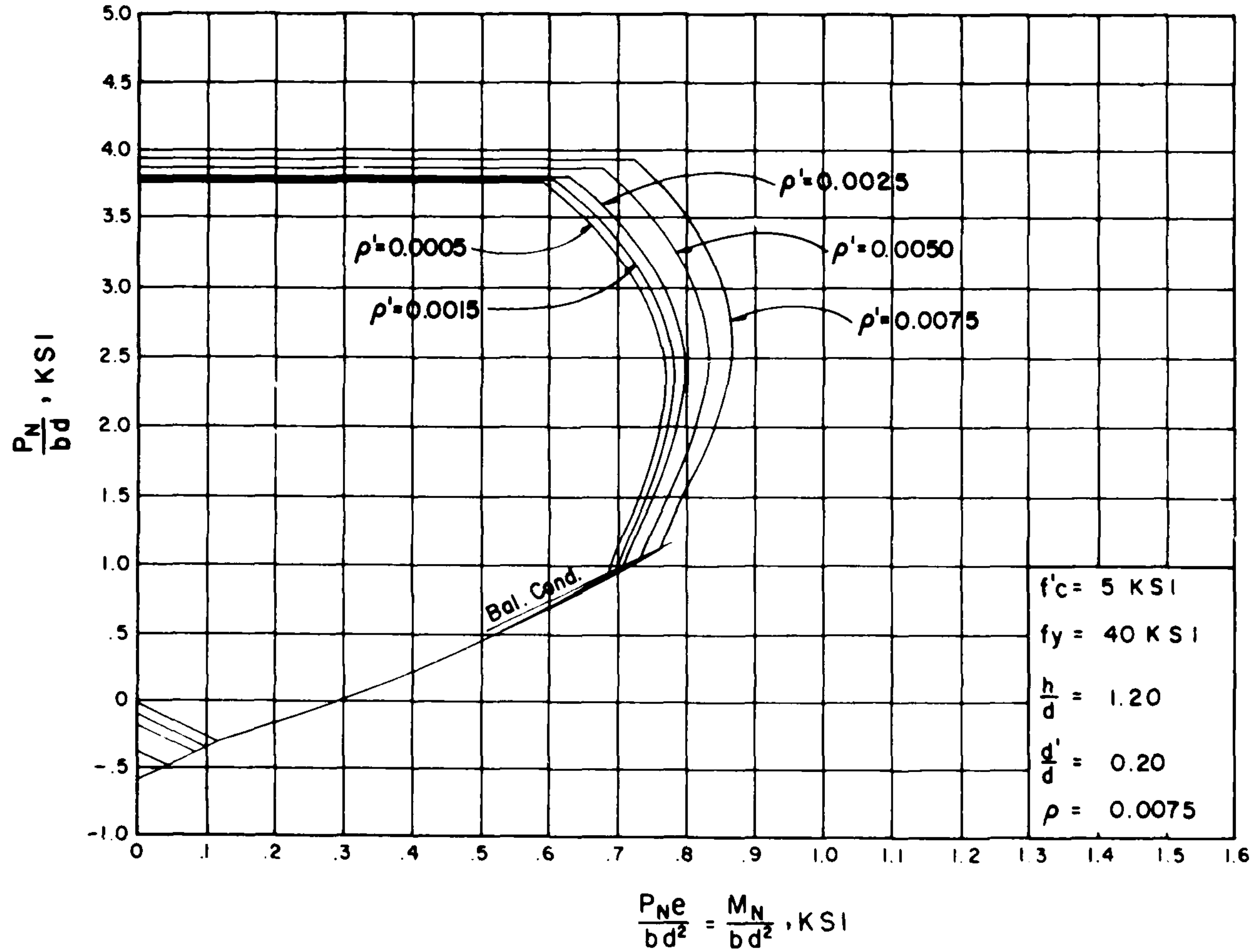


Figure 150. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0075)

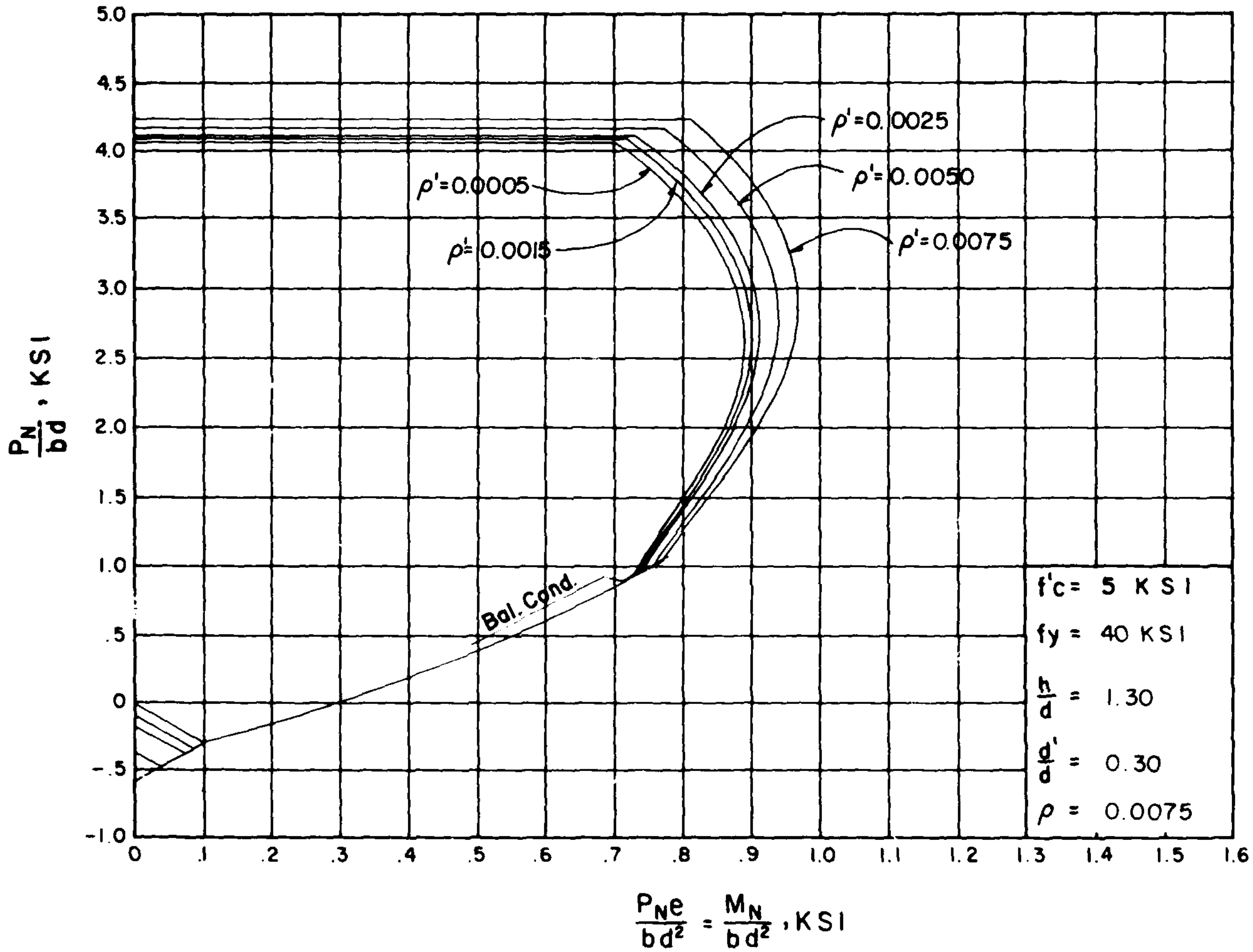


Figure 151. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0075)

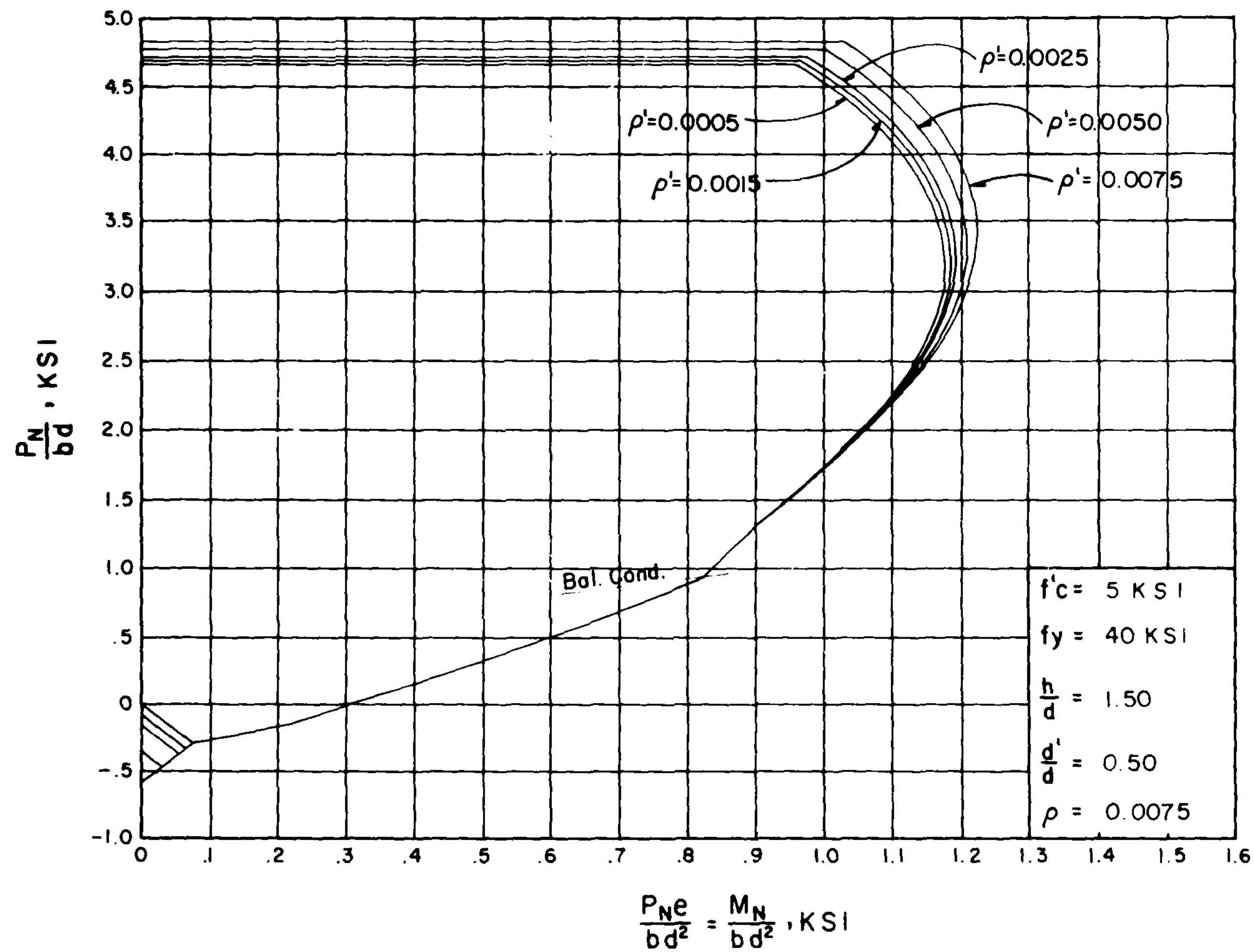


Figure 153. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0075)

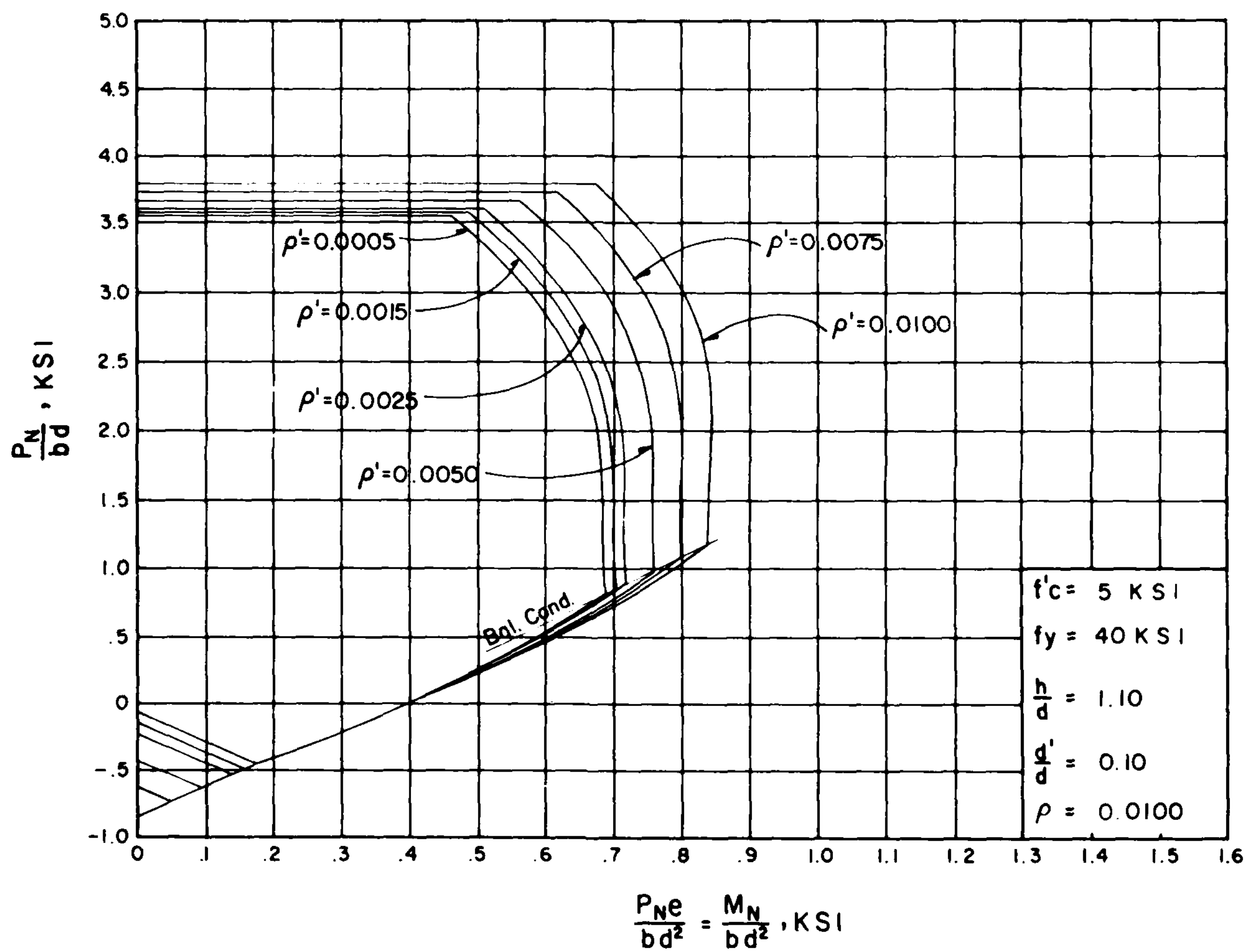


Figure 154. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0100)

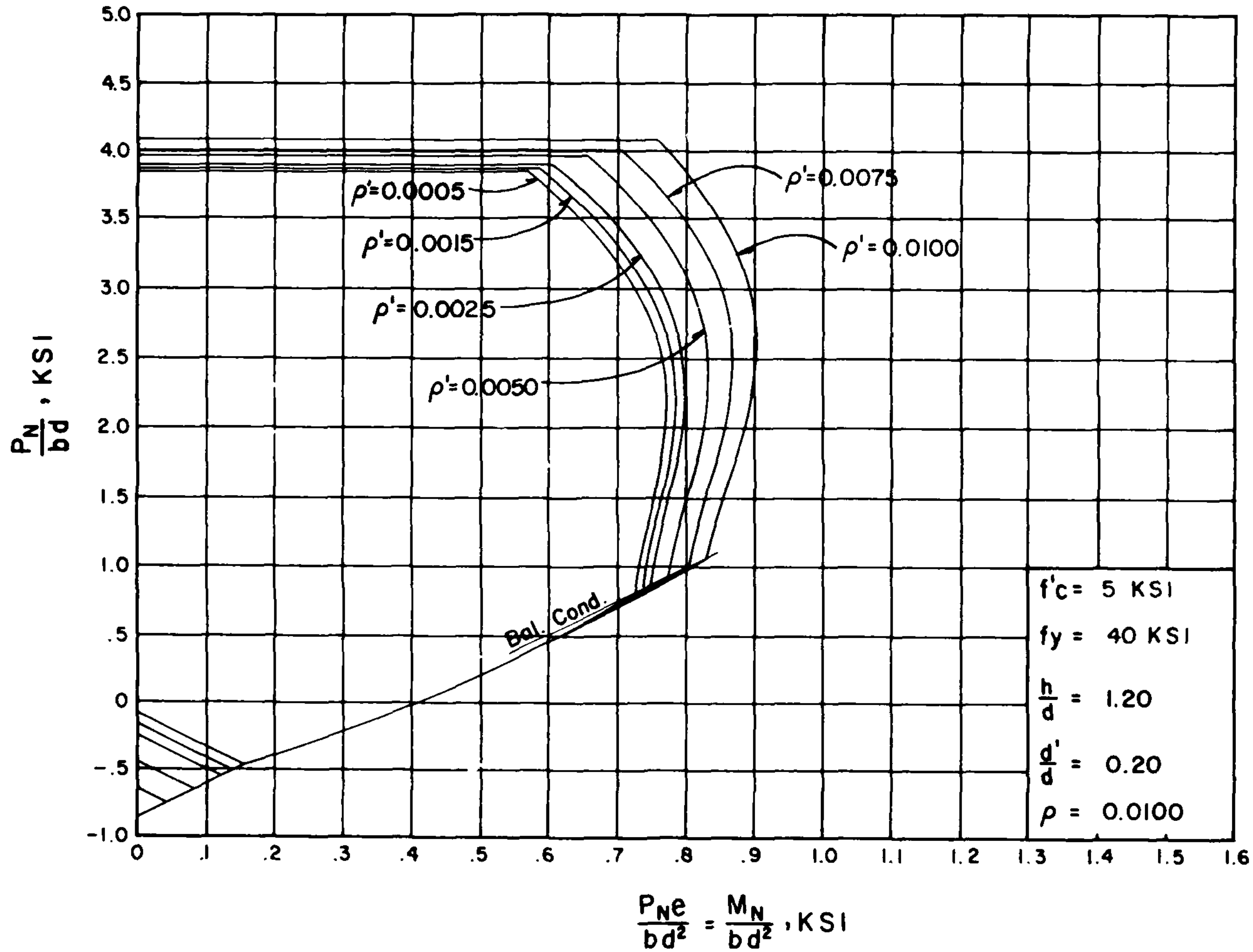


Figure 155. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0100)

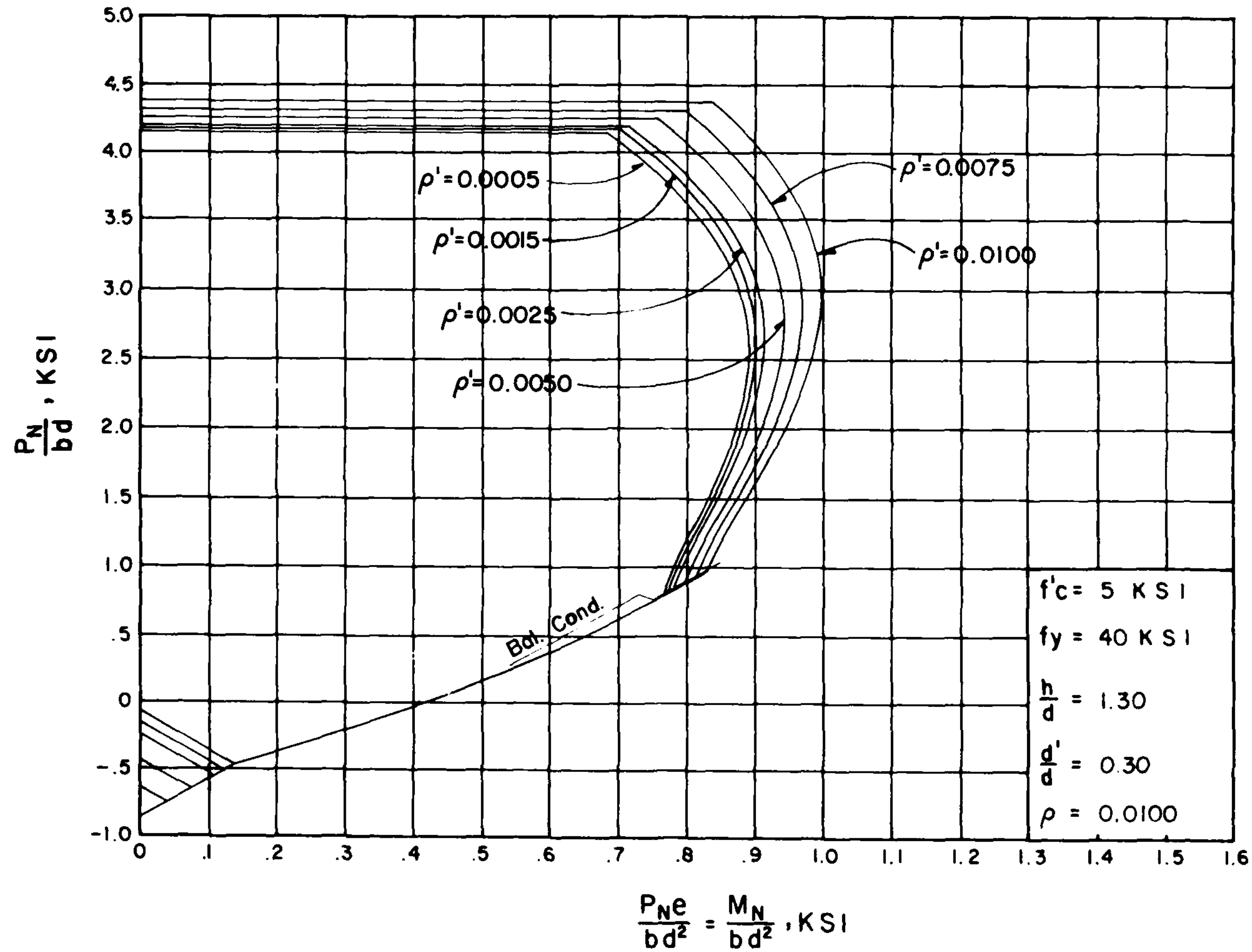


Figure 156. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0100)

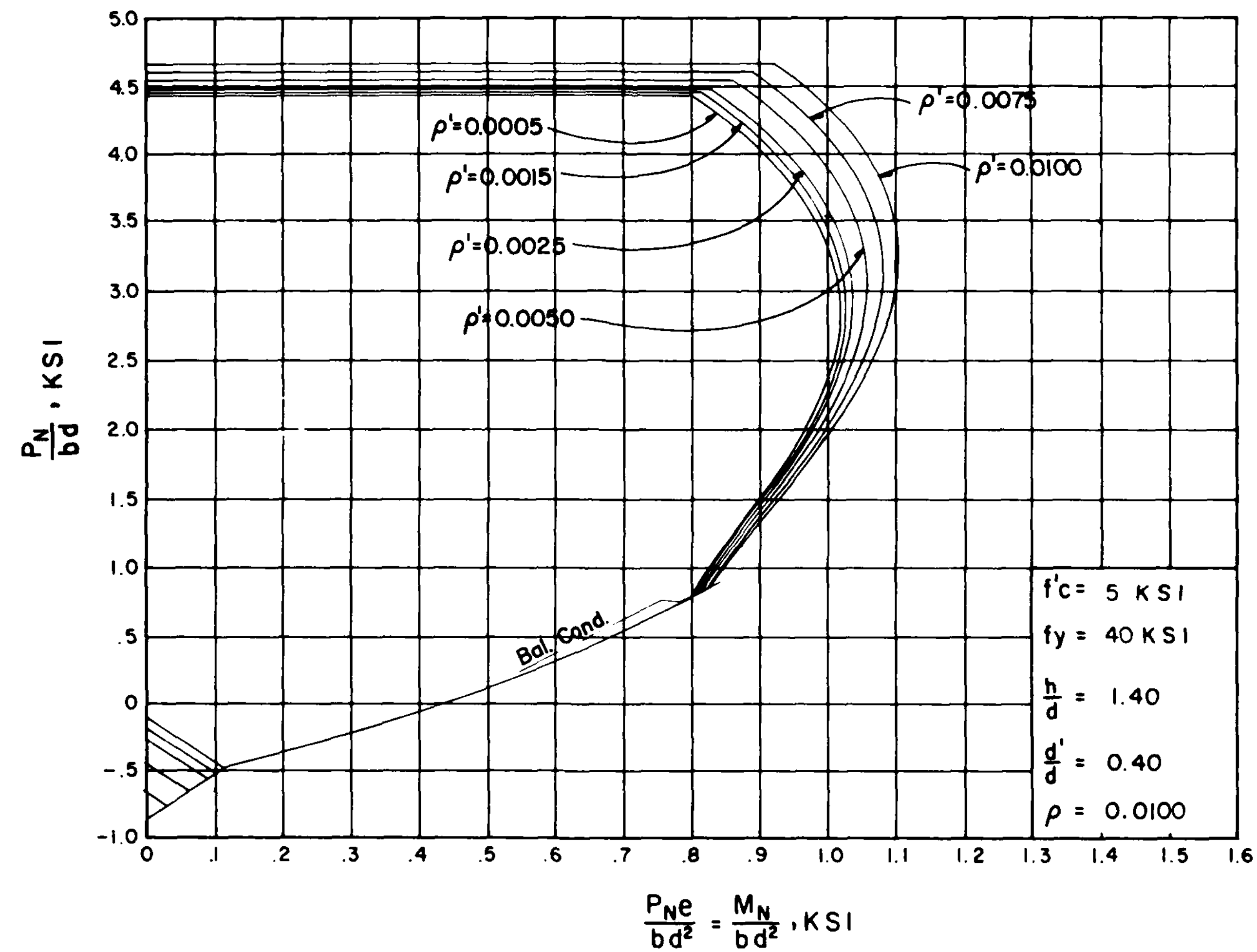


Figure 157. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0100)

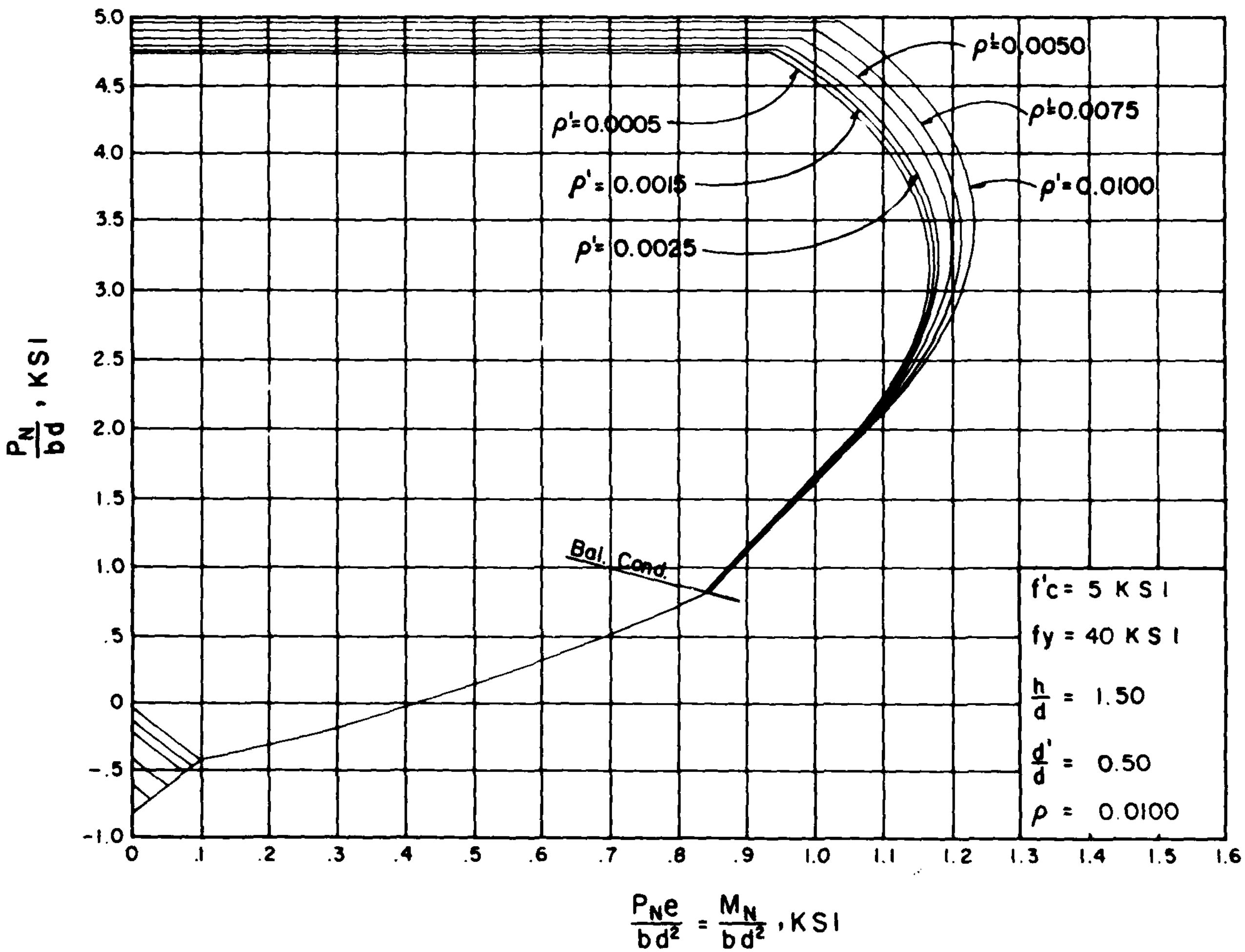


Figure 158. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0100)

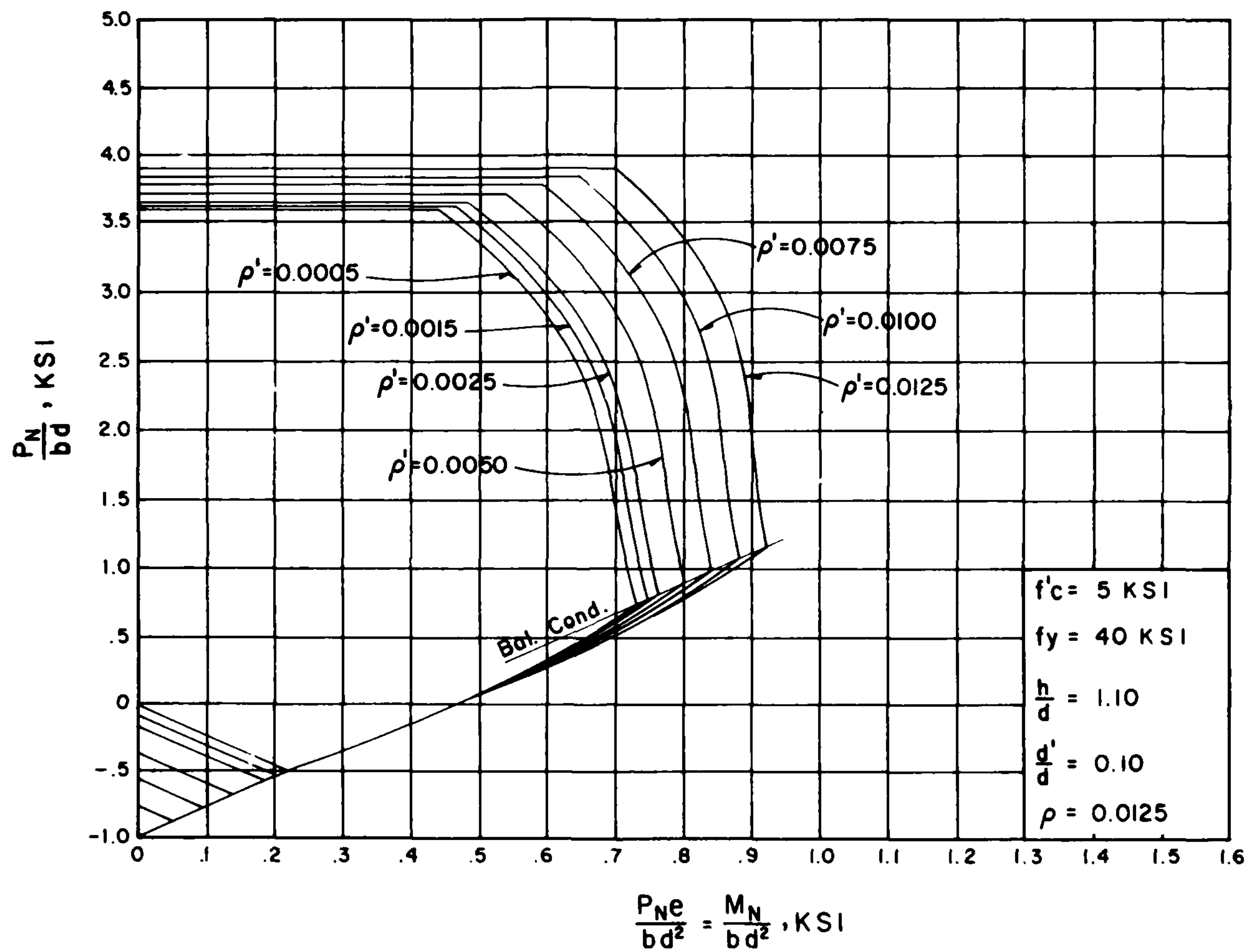


Figure 159. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0125)

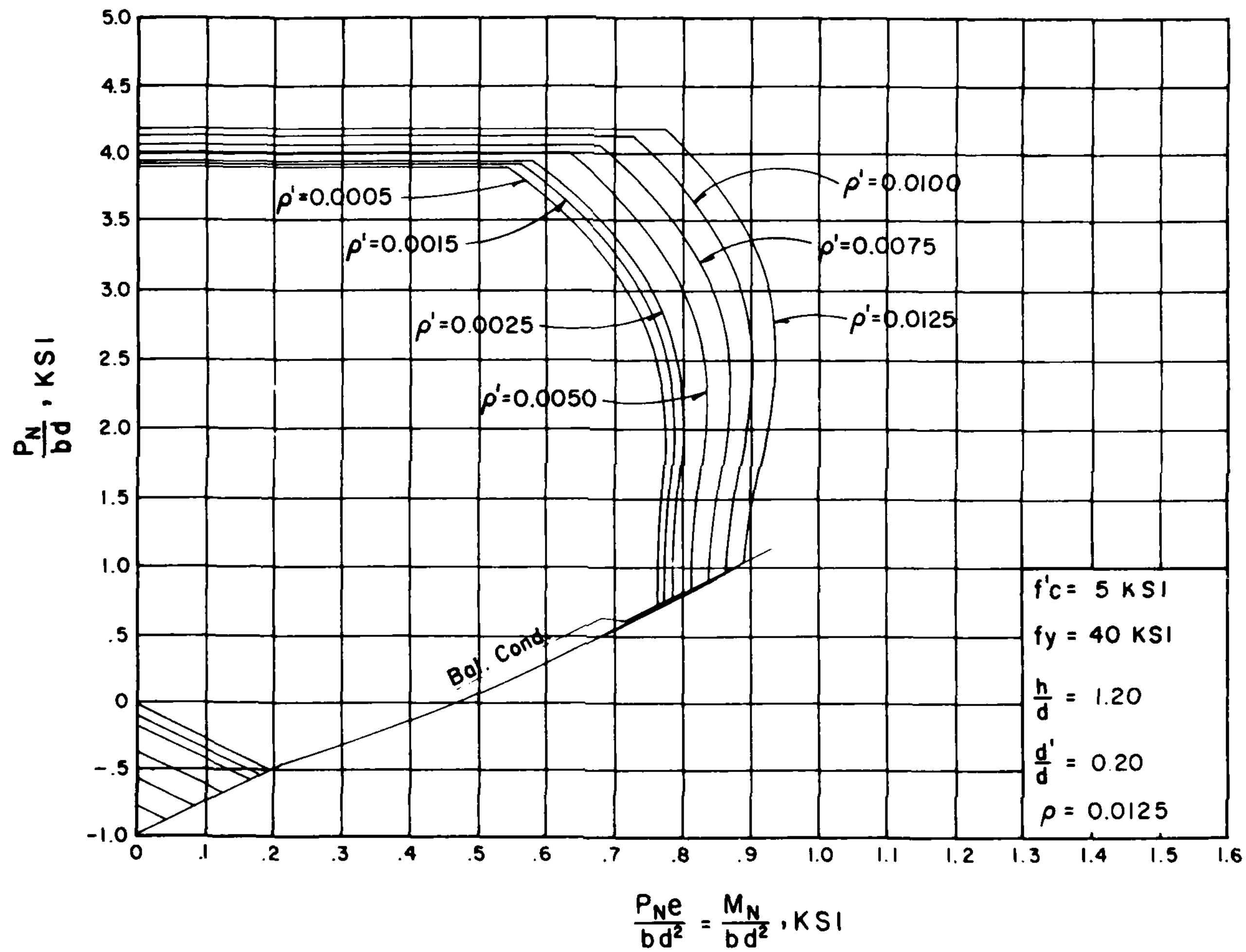


Figure 160. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0125)

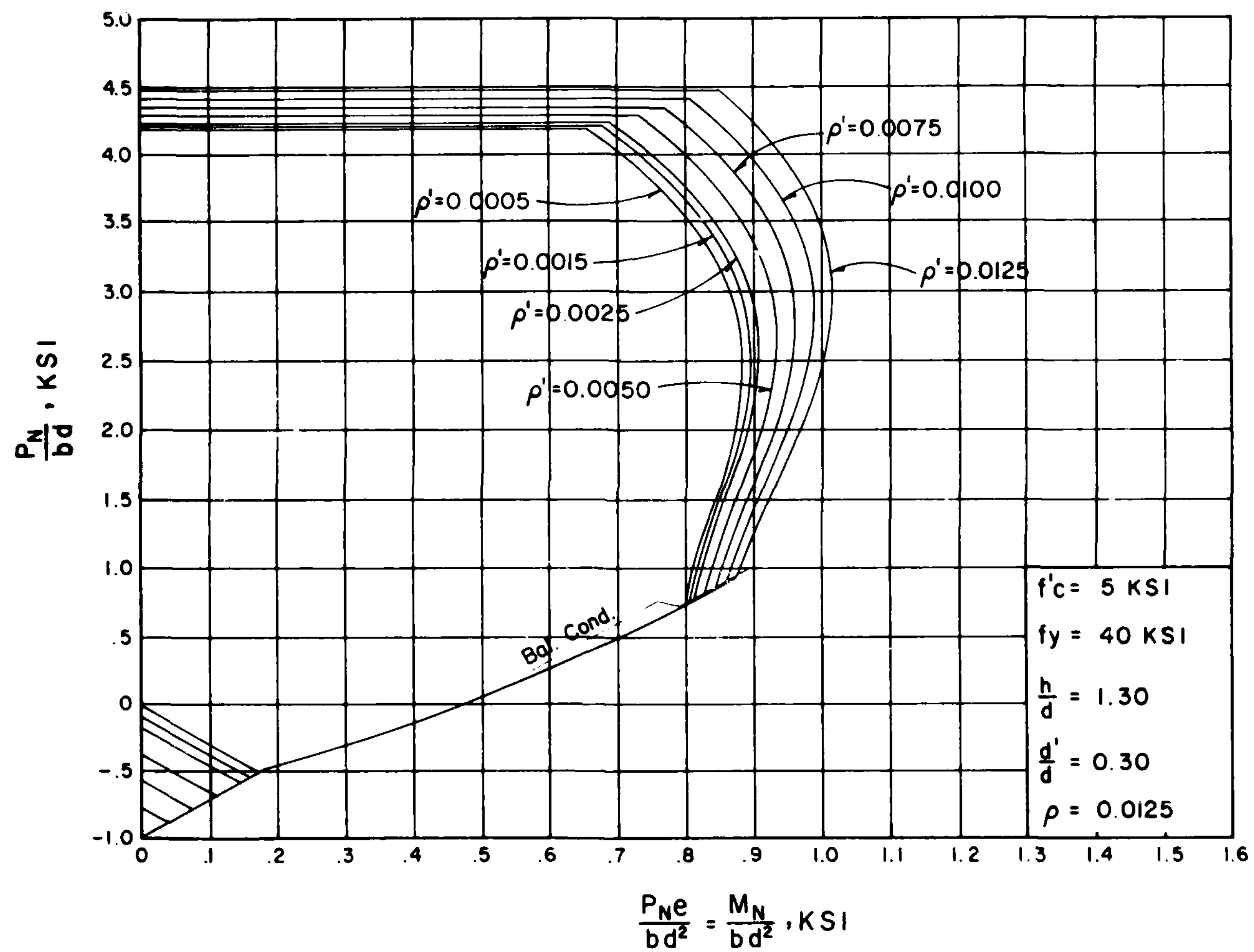


Figure 161. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0125)

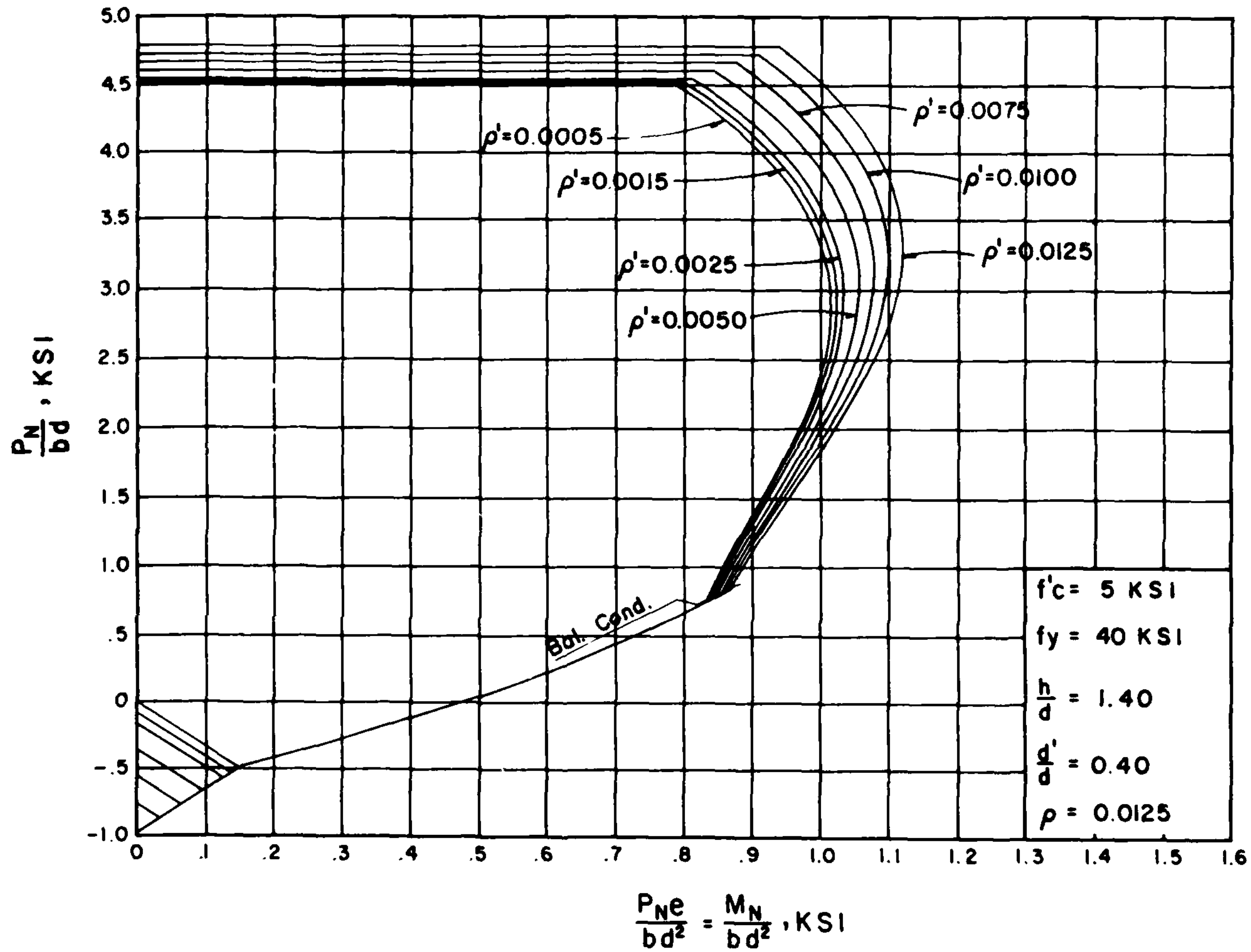


Figure 162. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0125)

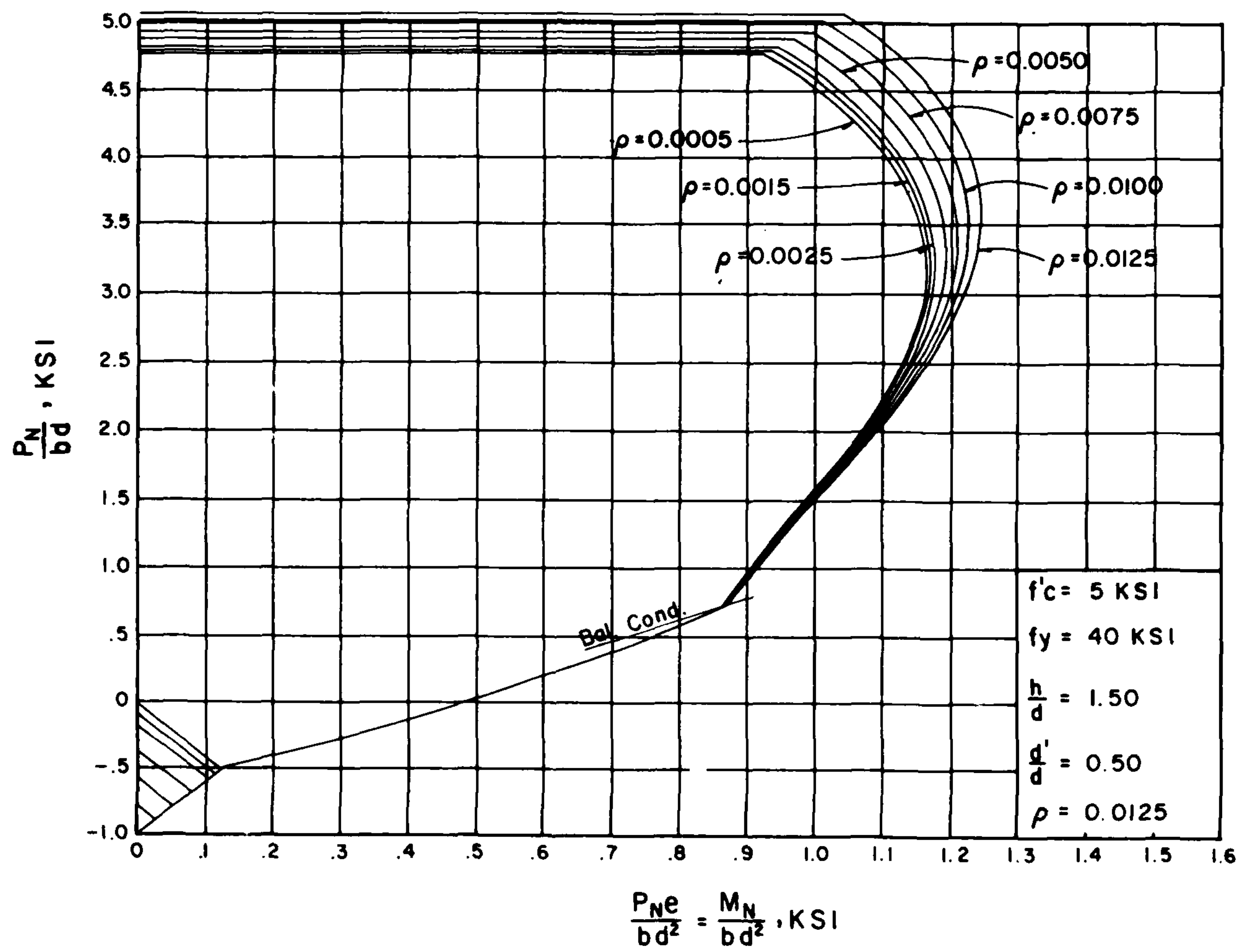


Figure 163. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0125)

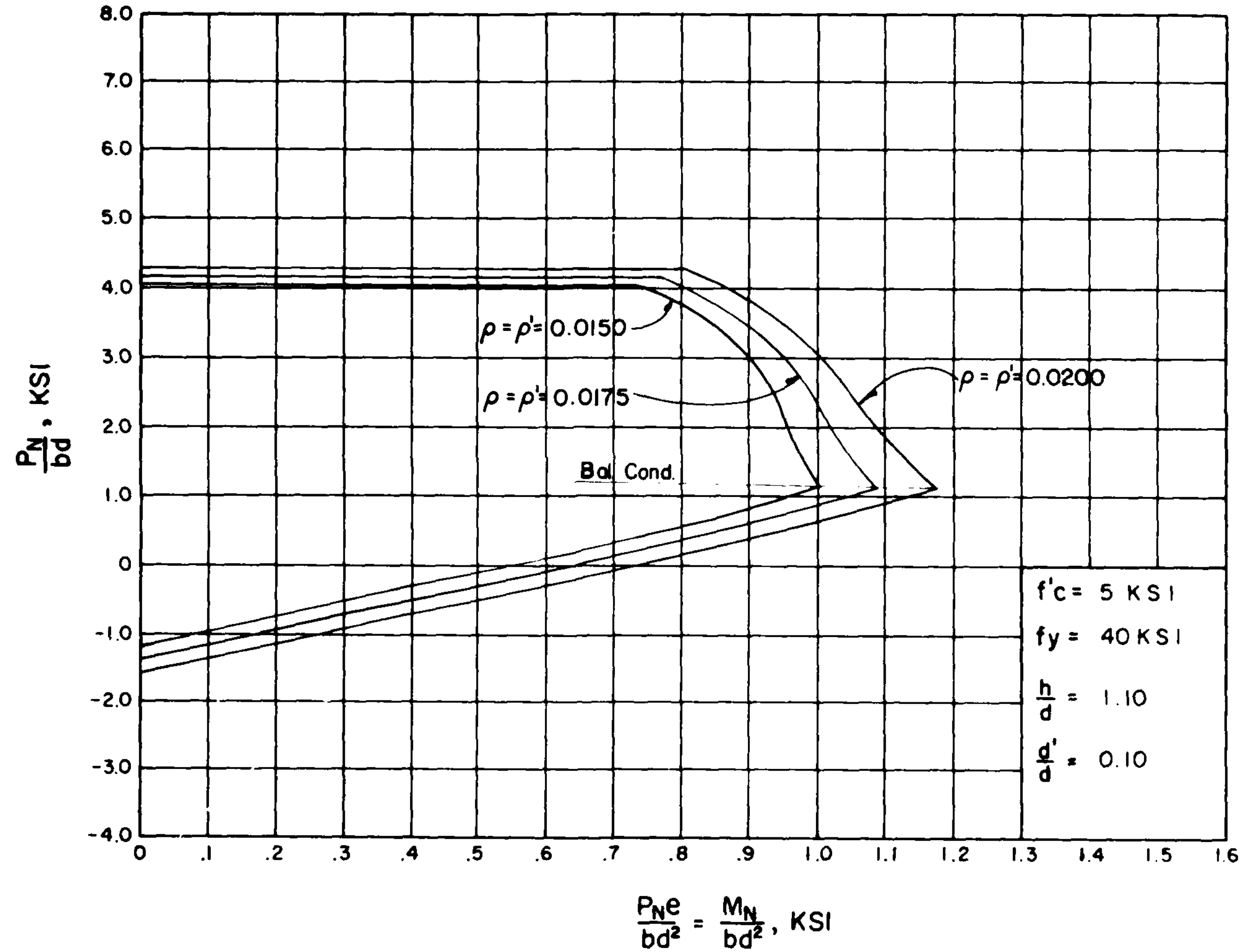


Figure 164. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.10, and d'/d = 0.10)

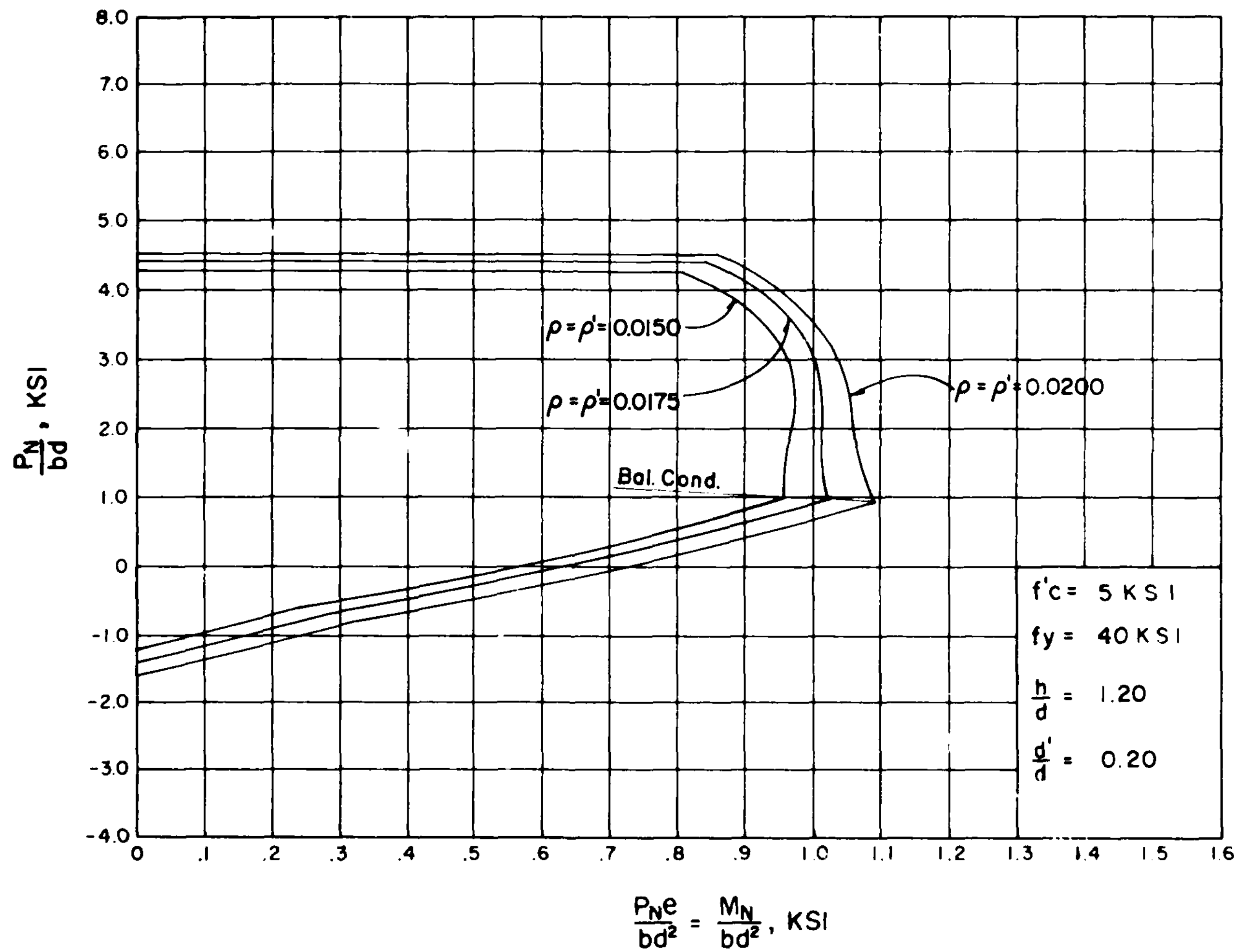
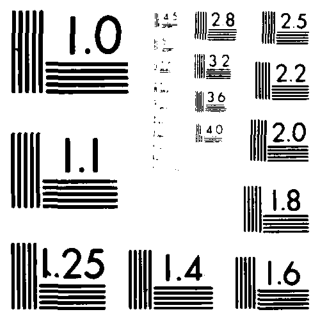


Figure 165. Load-moment strength interaction diagram for double reinforced members ($f'_c = 5$ ksi, $f_y = 40$ ksi, $h/d = 1.20$, and $d'/d = 0.20$)

AD-A111 648 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/13
STRENGTH DESIGN OF REINFORCED CONCRETE HYDRAULIC STRUCTURES. RE--ETC(U)
DEC 81 T C LIU, S GLEASON
UNCLASSIFIED WES/TR/SL-80-4 NL

3 OF 3
AD
A111648

END
DATE
FILMED
3-82
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

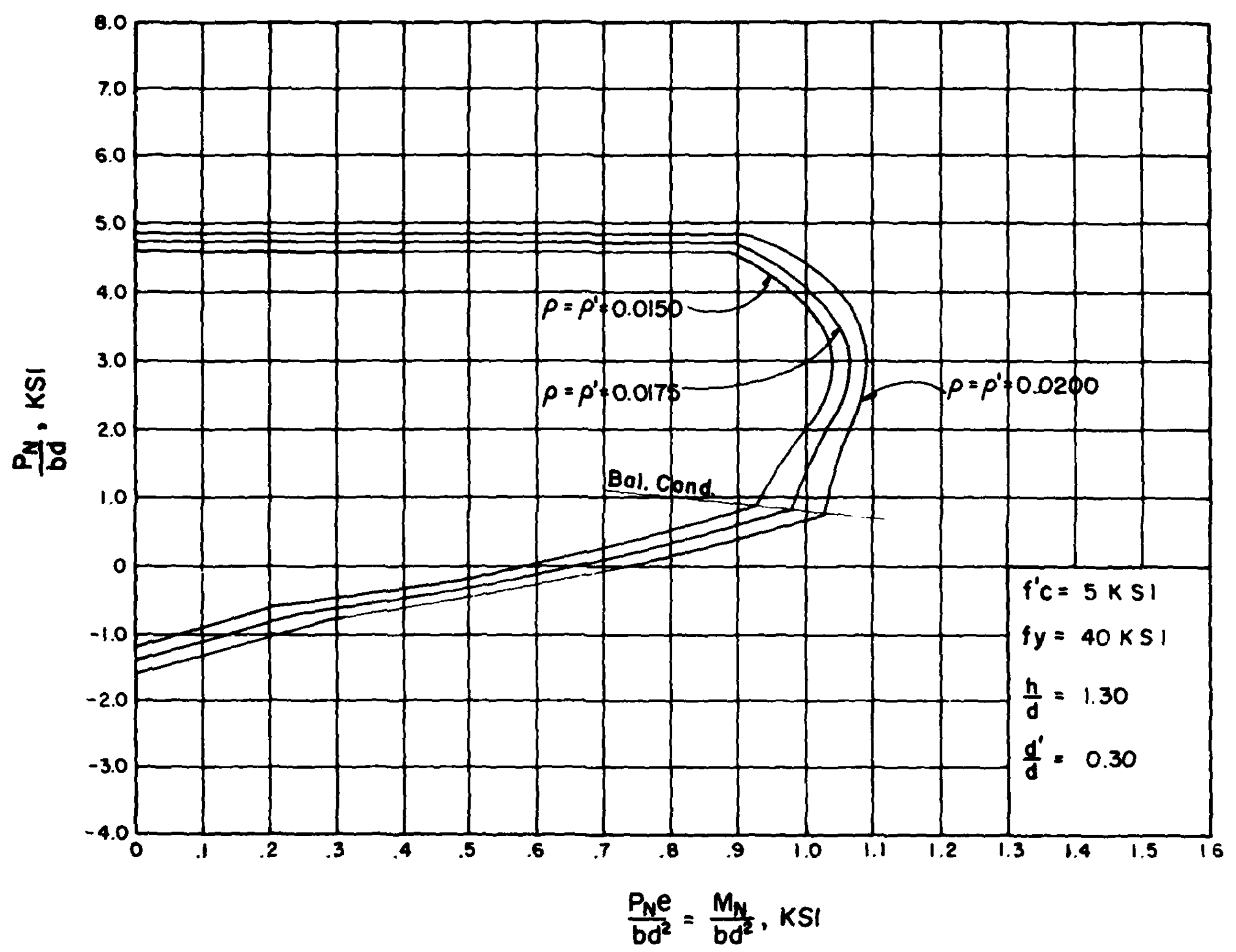


Figure 166. Load-moment strength interaction diagram for double reinforced members ($f'_c = 5$ ksi, $f_y = 40$ ksi, $h/d = 1.30$, and $d'/d = 0.30$)

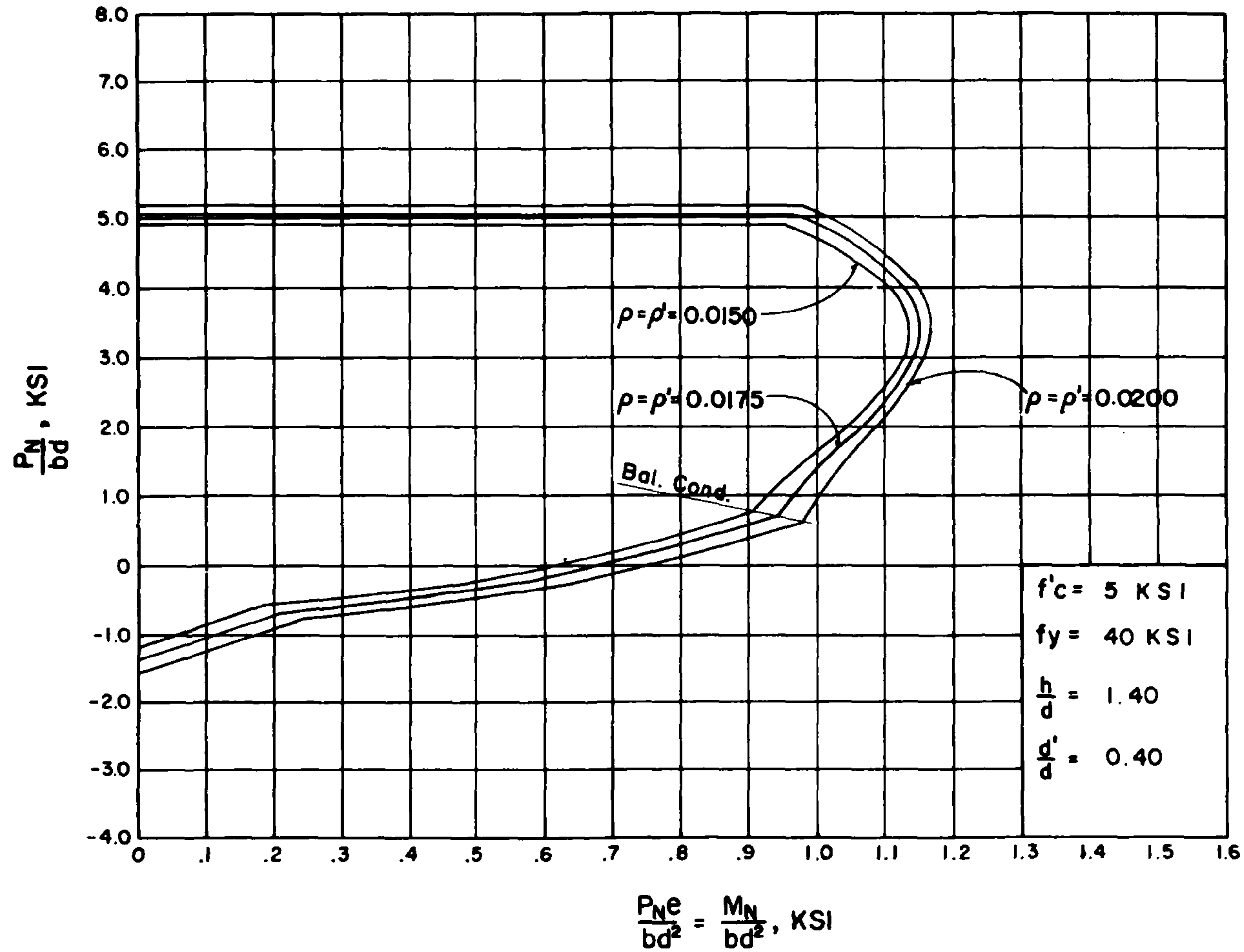


Figure 167. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.40, and d'/d = 0.40)

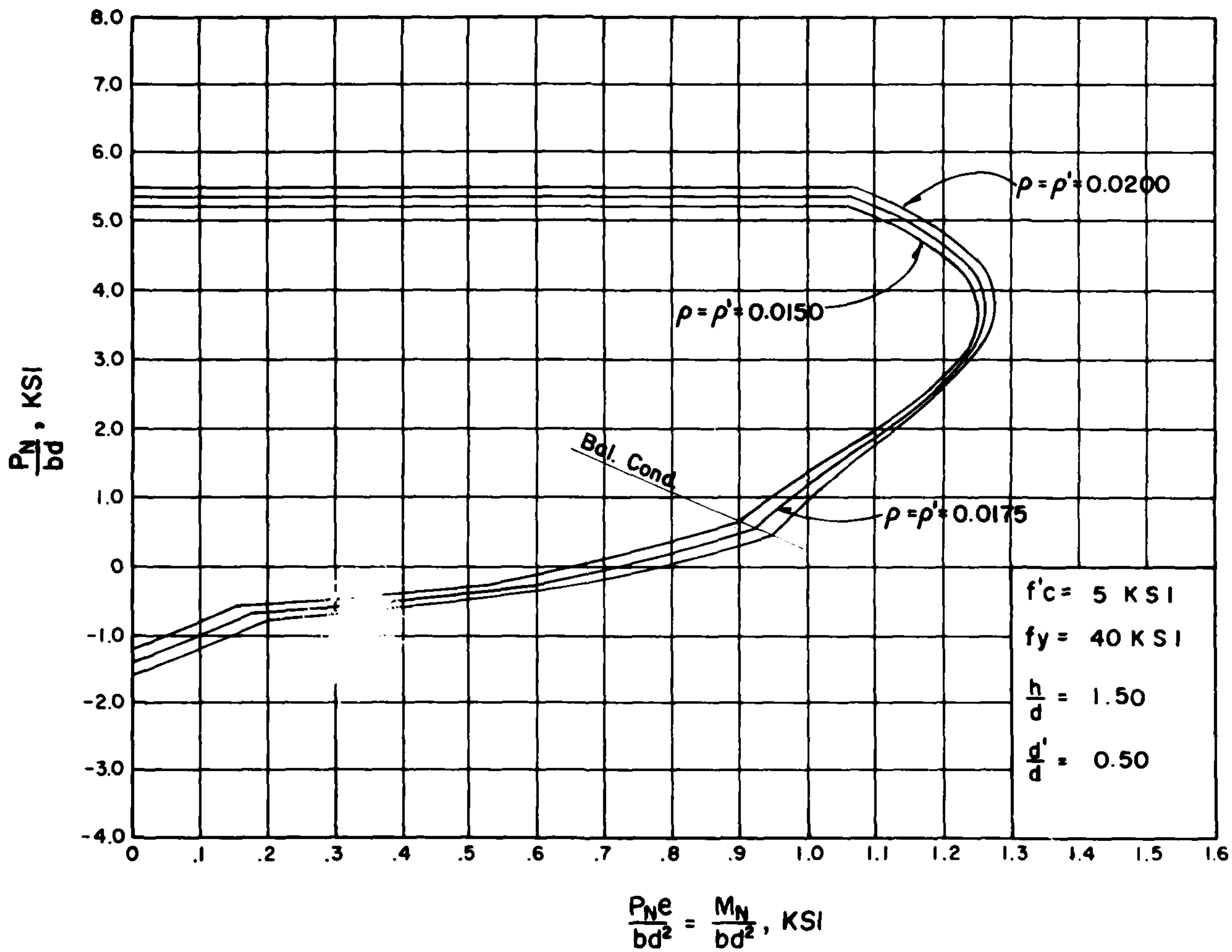


Figure 168. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 40 ksi, h/d = 1.50, and d'/d = 0.50)

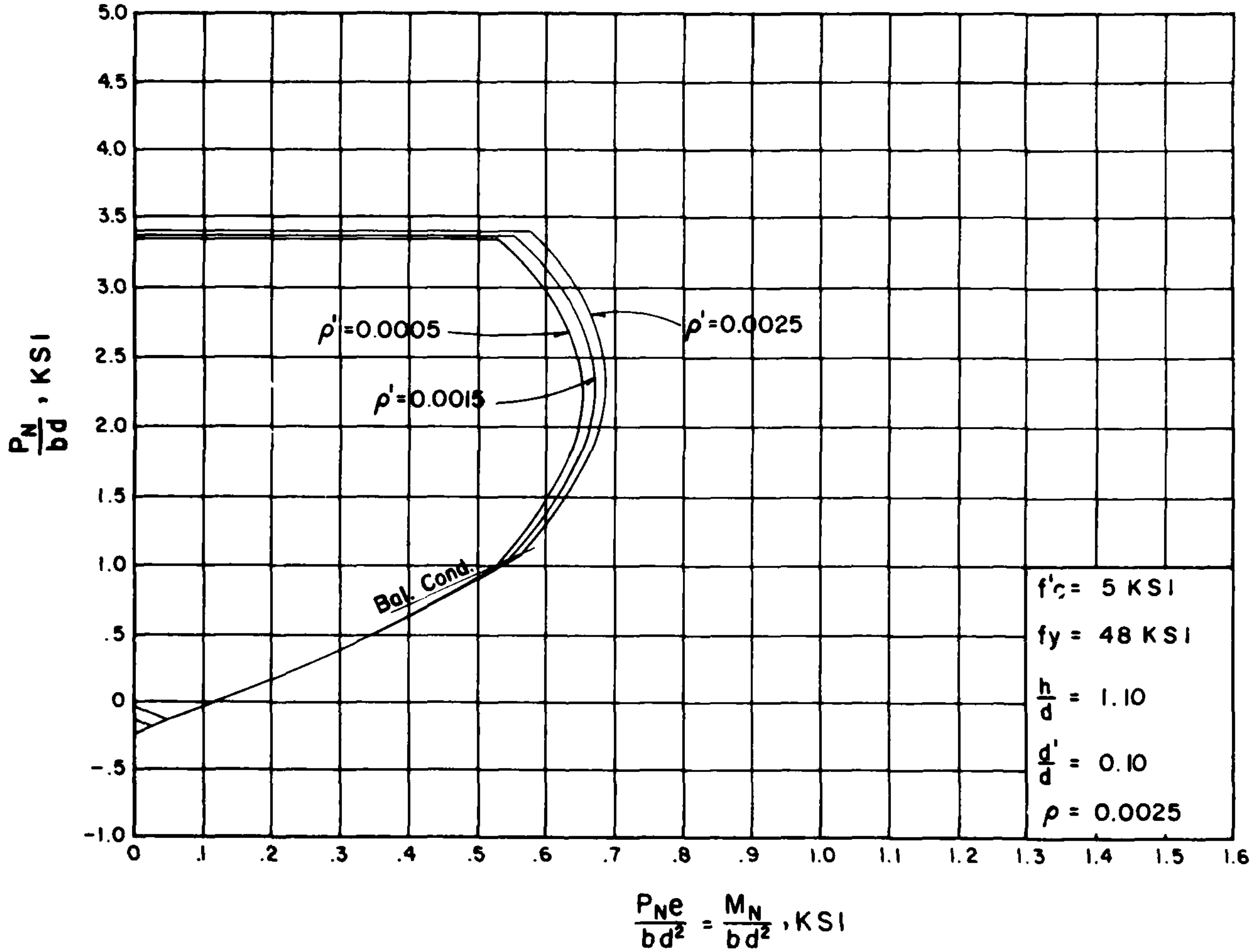


Figure 169. Load-moment strength interaction diagram for double reinforced members ($f'_c = 5$ ksi, $f_y = 48$ ksi, $h/d = 1.10$, $d'/d = 0.10$, and $\rho = 0.0025$)

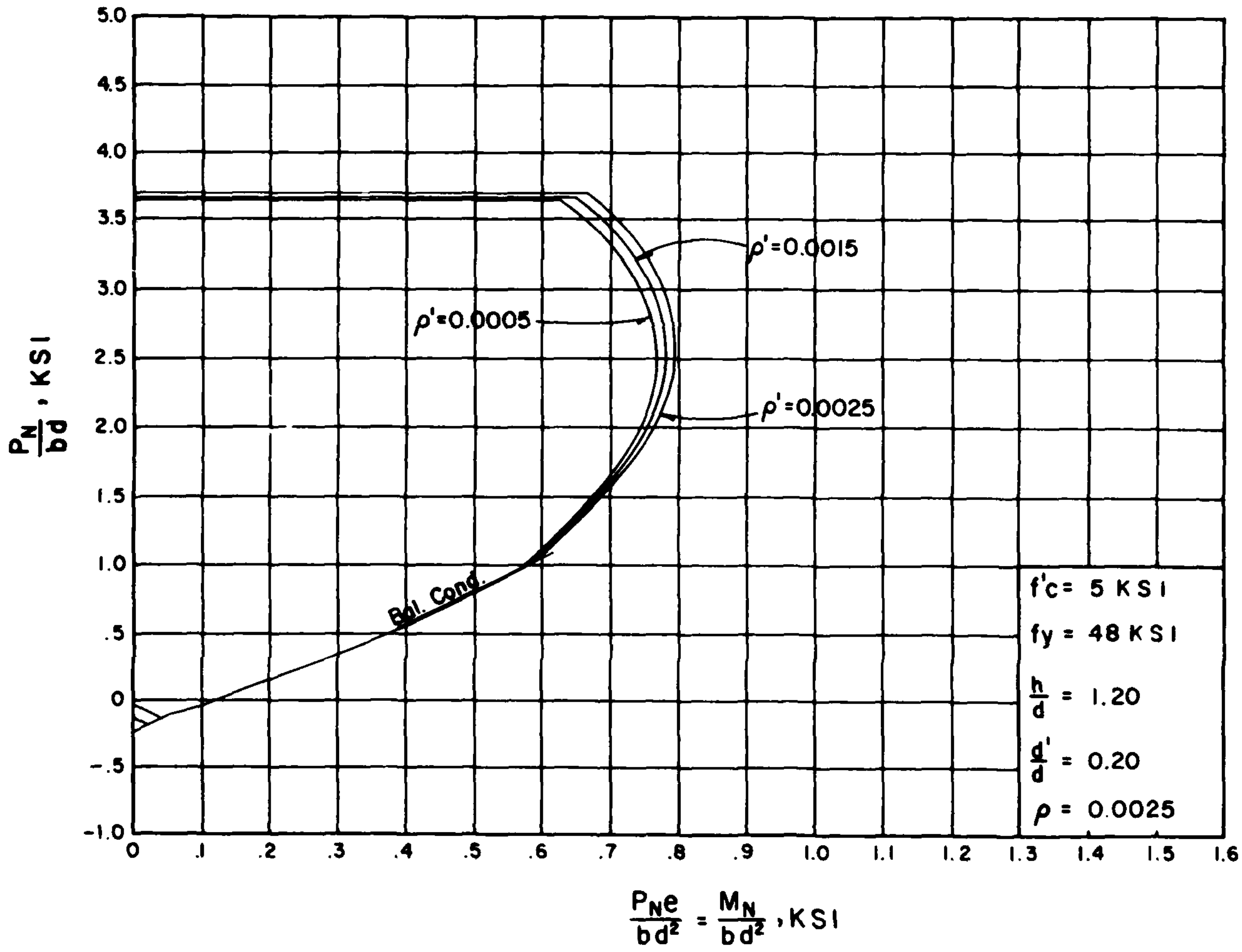


Figure 170. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0025)

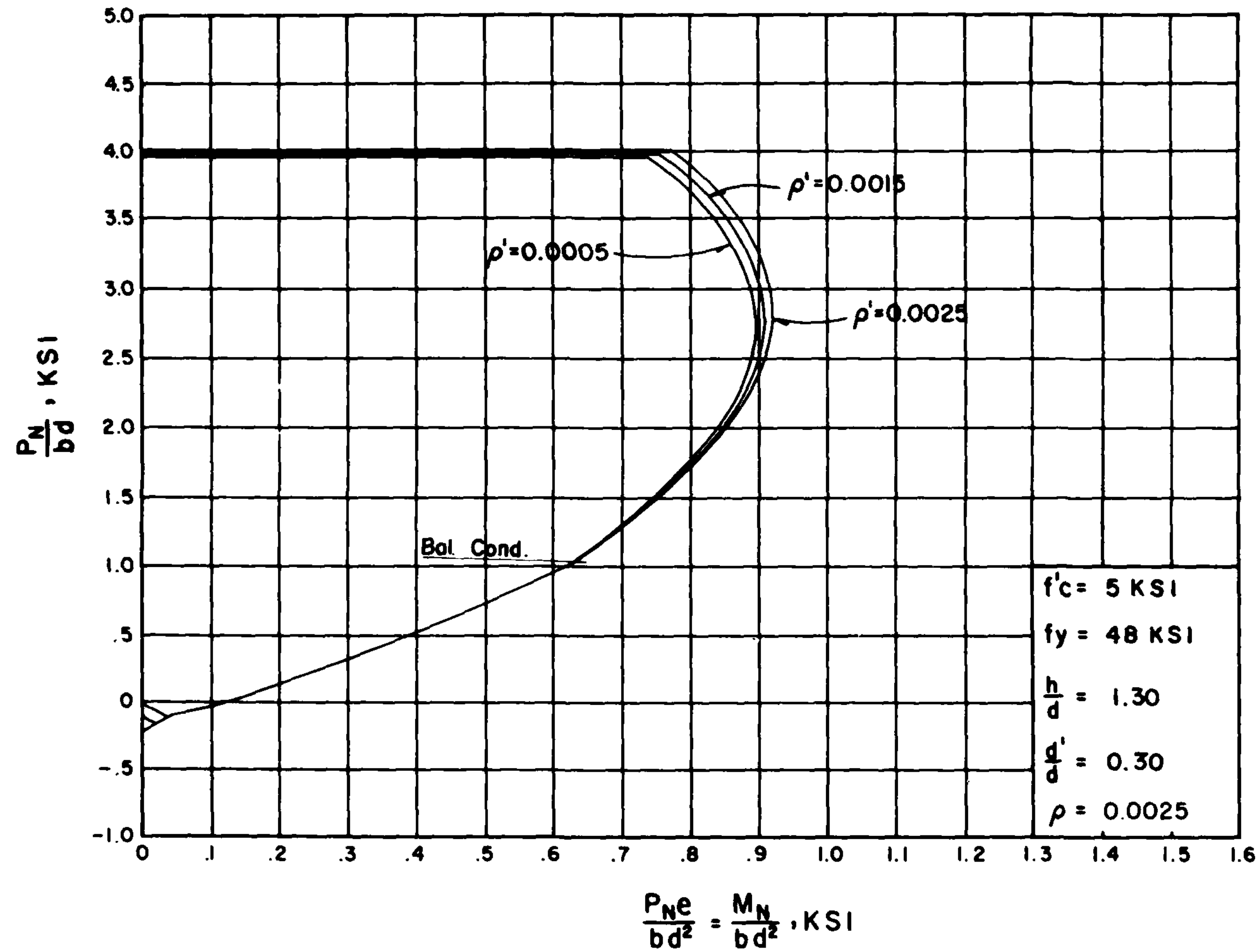


Figure 171. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0025)

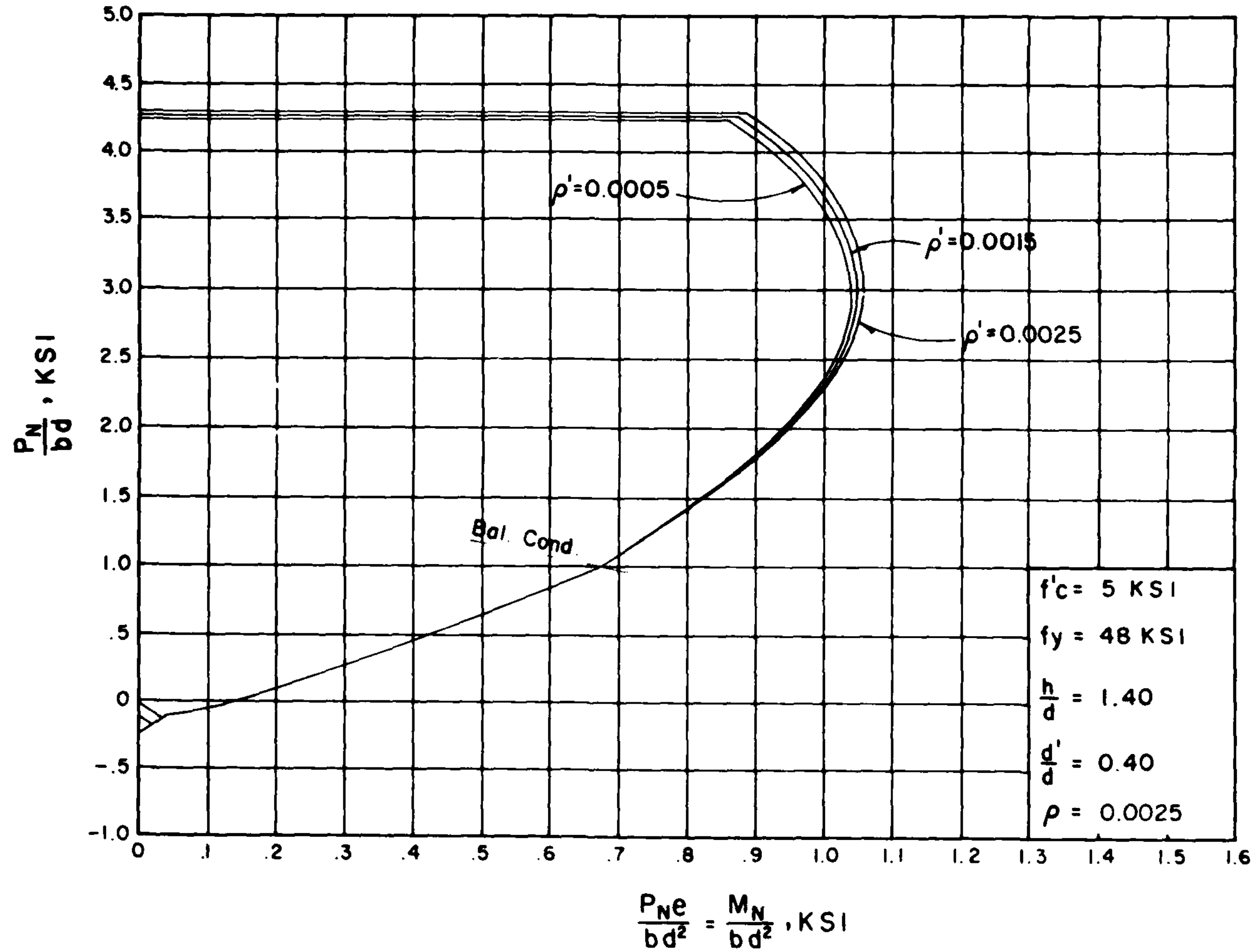


Figure 172. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0025)

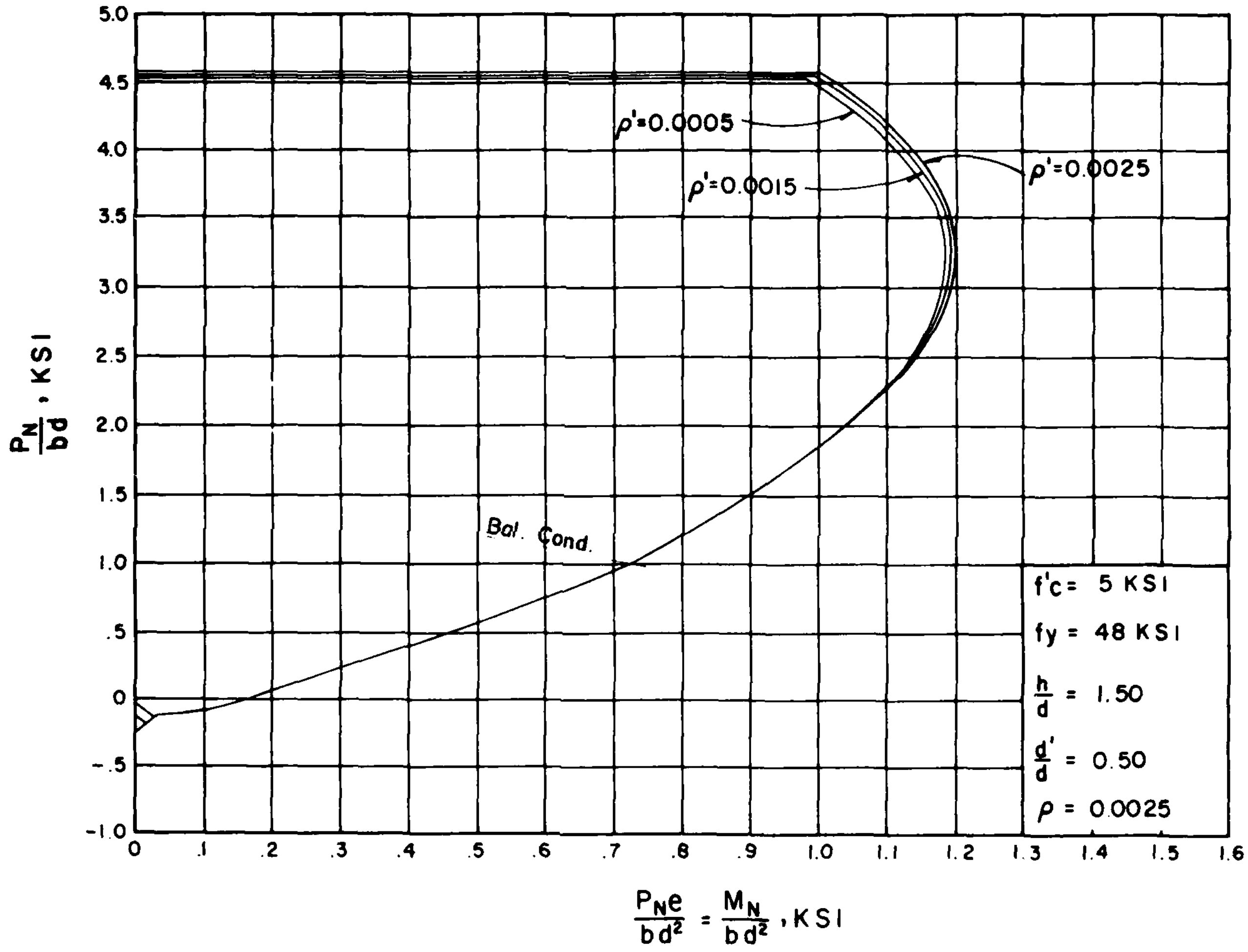


Figure 173. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0025)

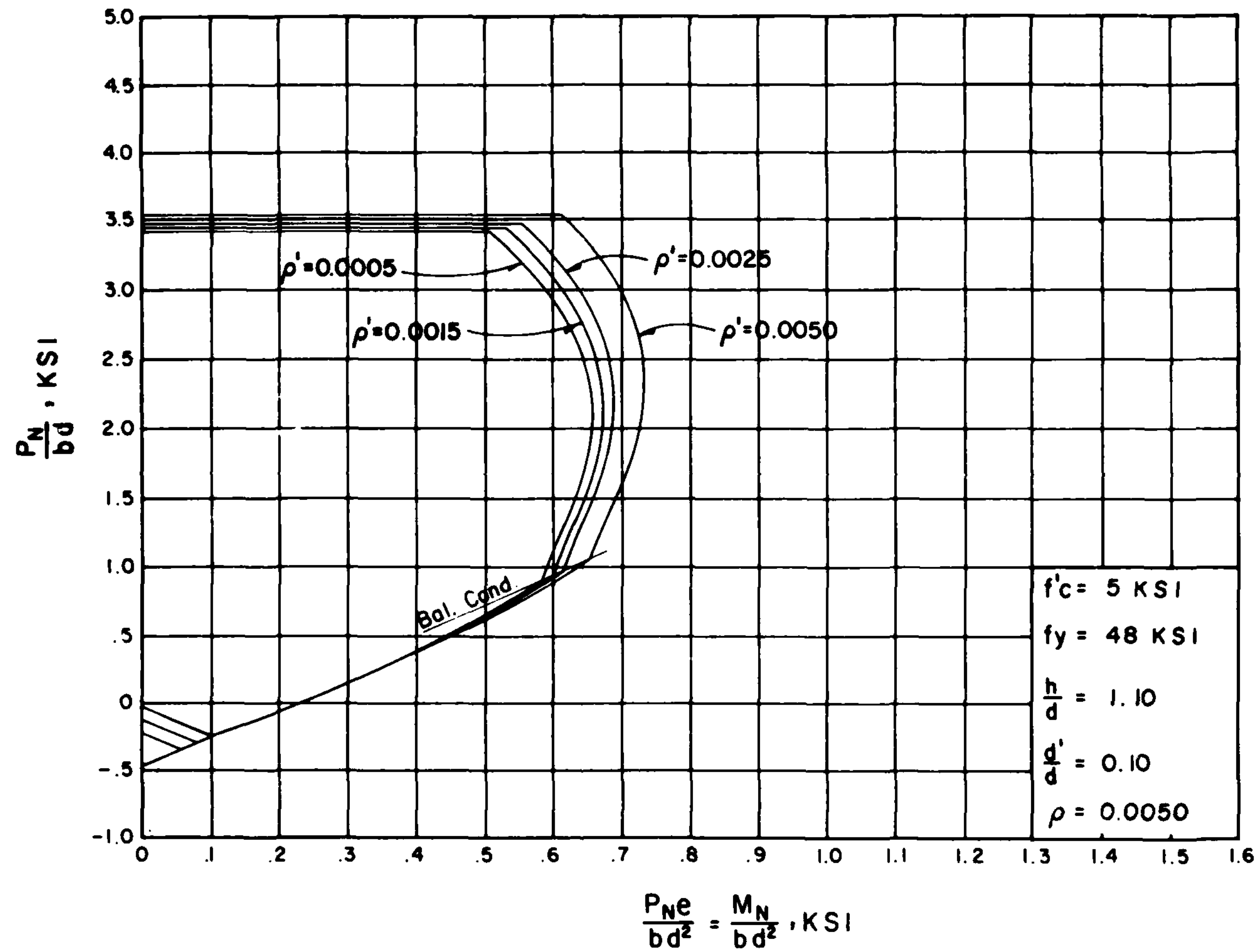


Figure 174. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0050)

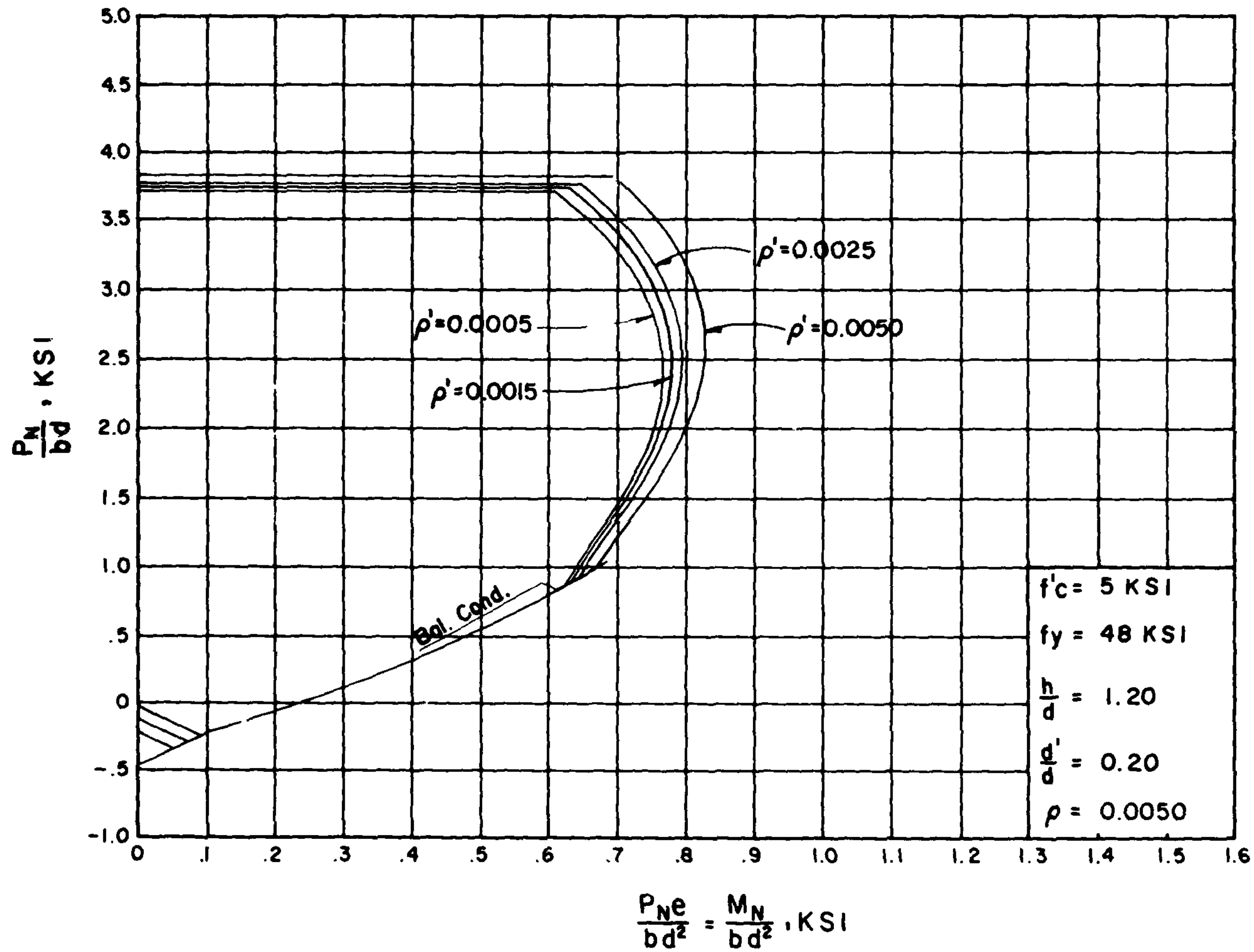


Figure 175. Load-moment strength interaction diagram for double reinforced members ($f'_c = 5$ ksi, $f_y = 48$ ksi, $h/d = 1.20$, $d'/d = 0.20$, and $\rho = 0.0050$)

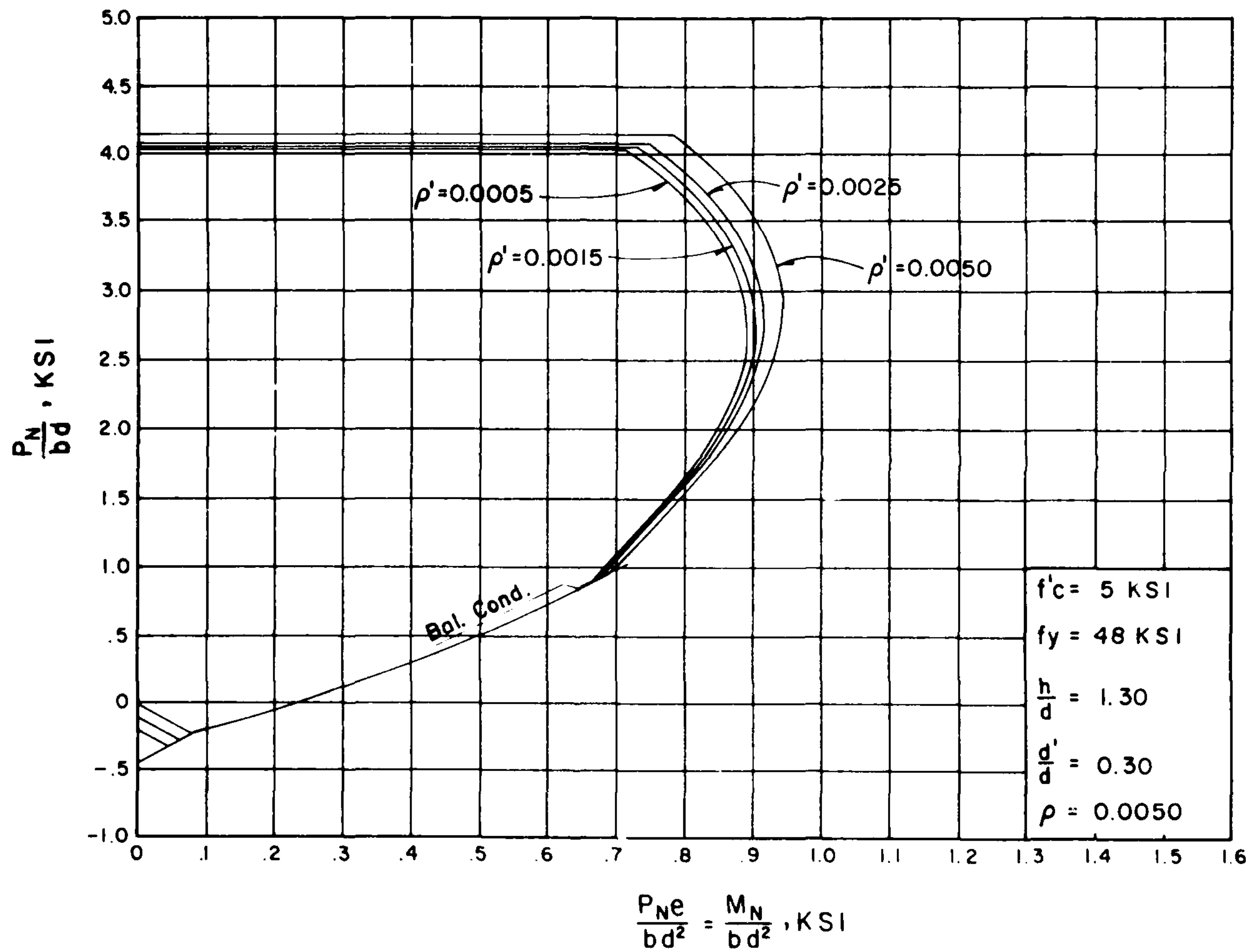


Figure 176. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0050)

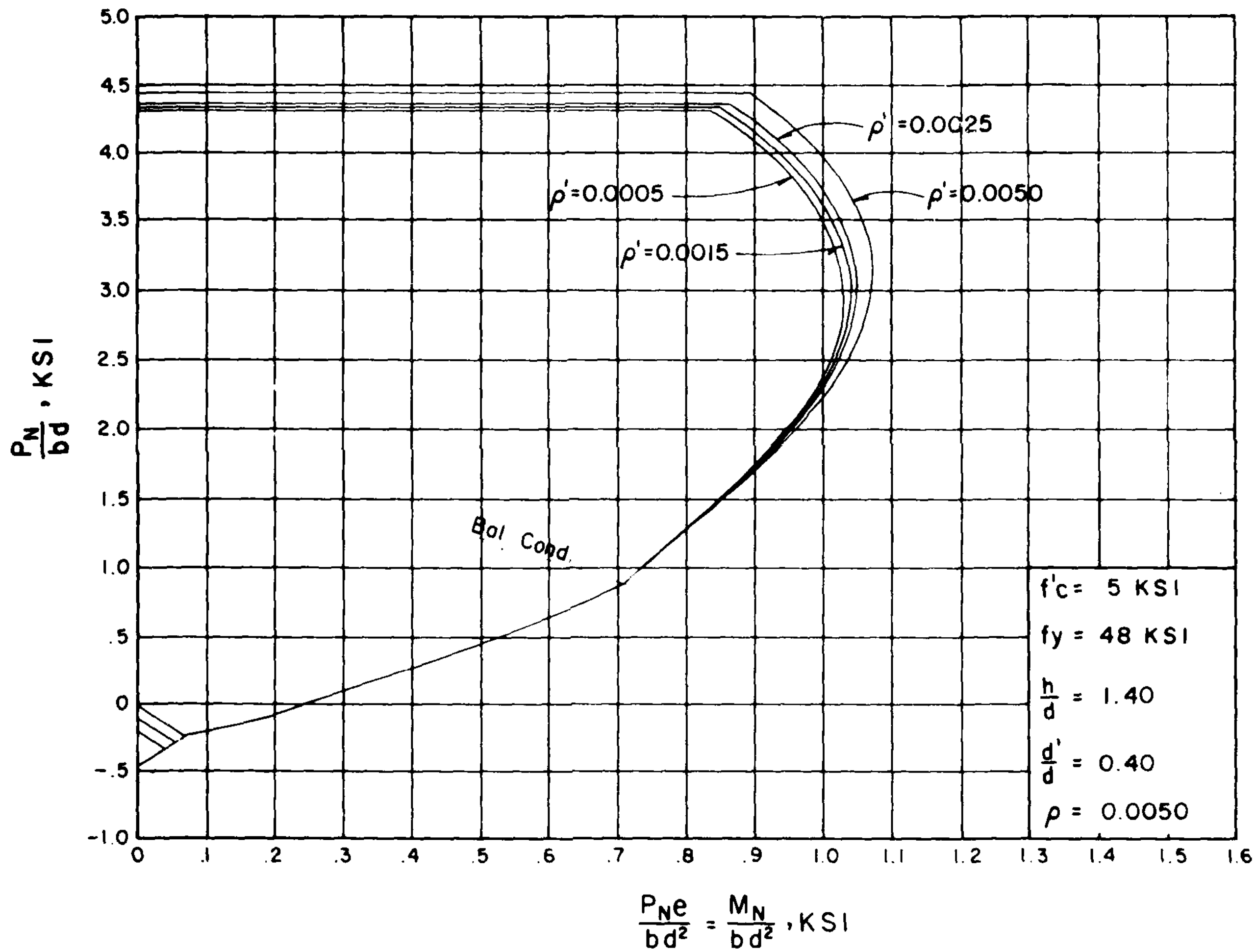


Figure 177. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0050)

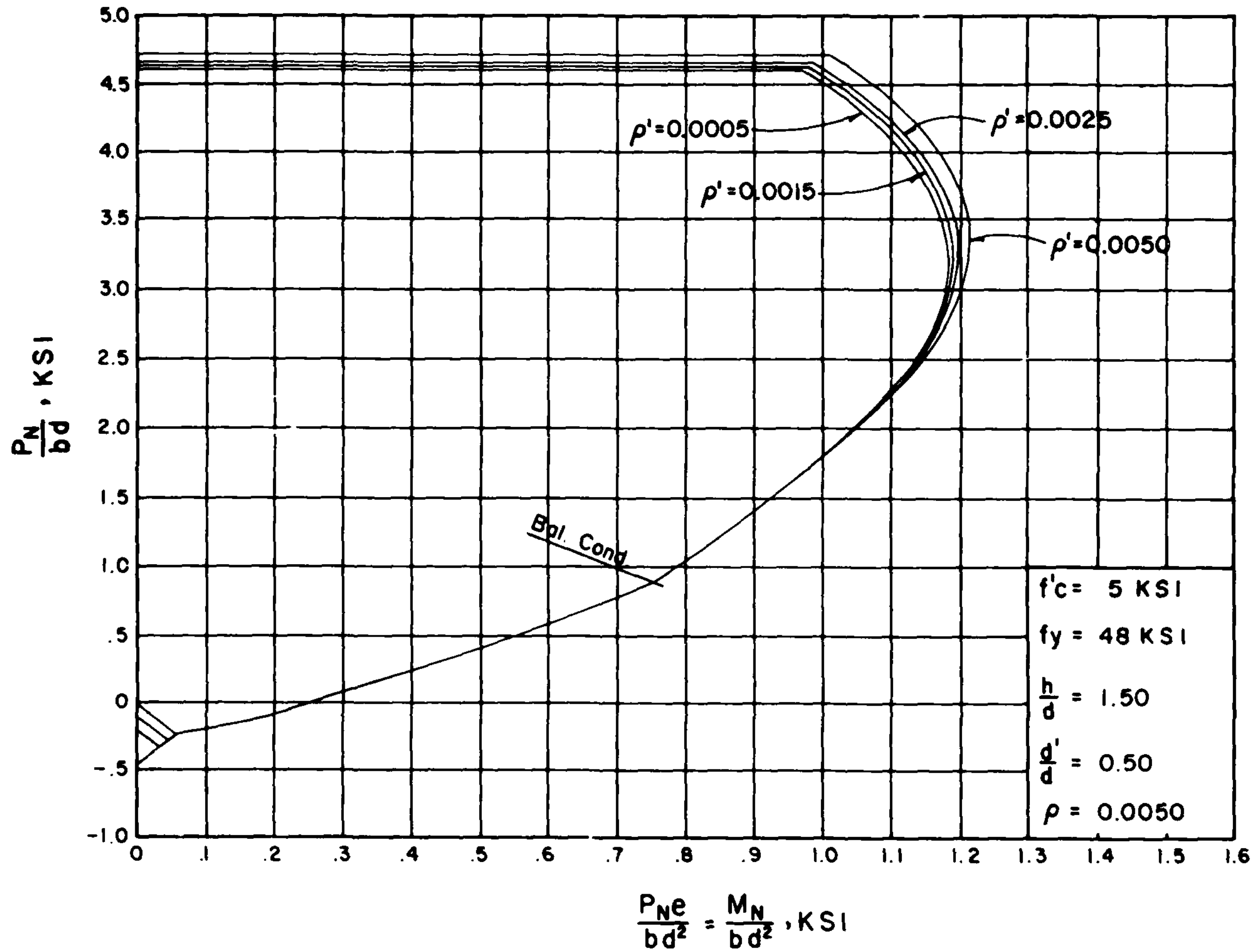


Figure 178. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0050)

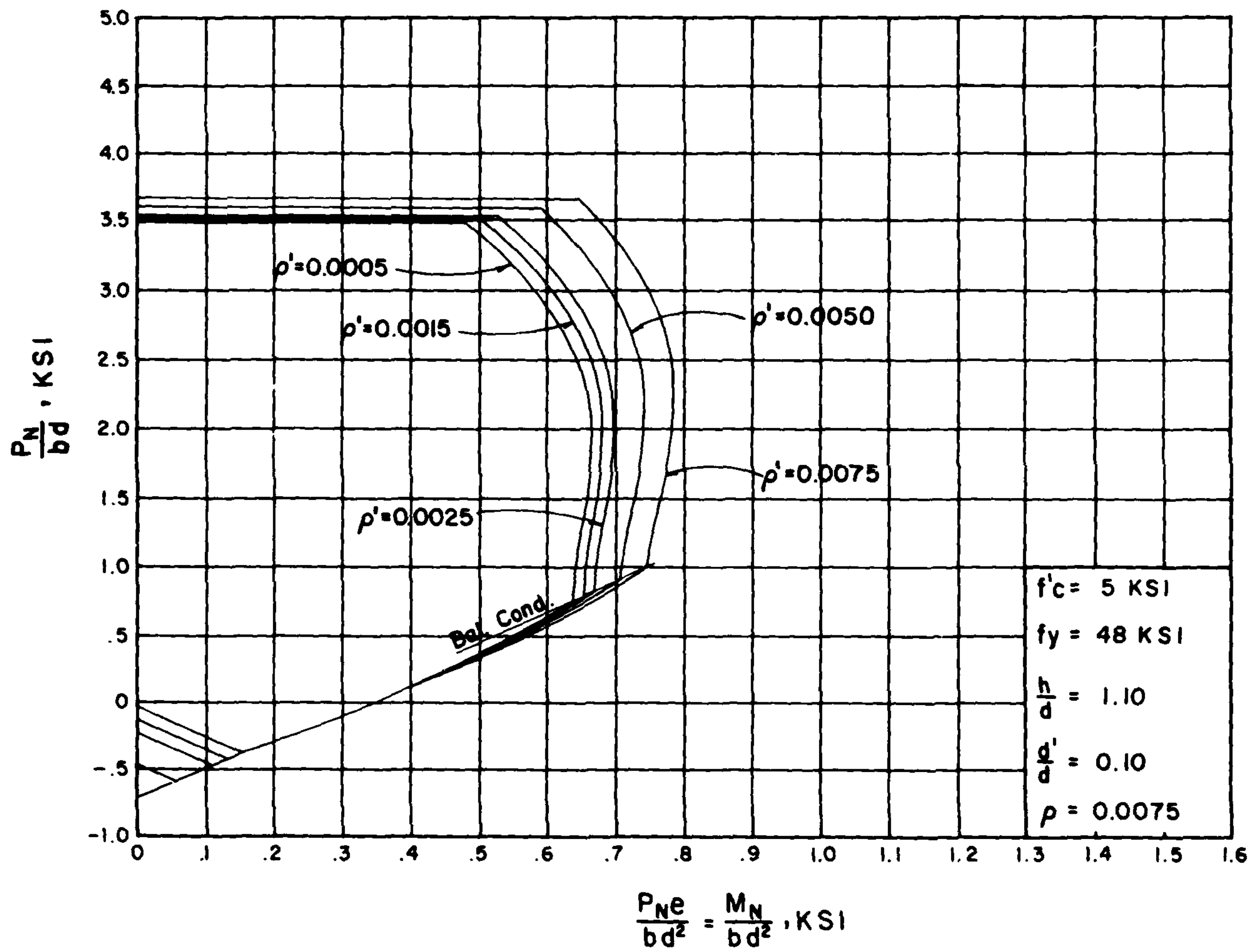


Figure 179. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0075)

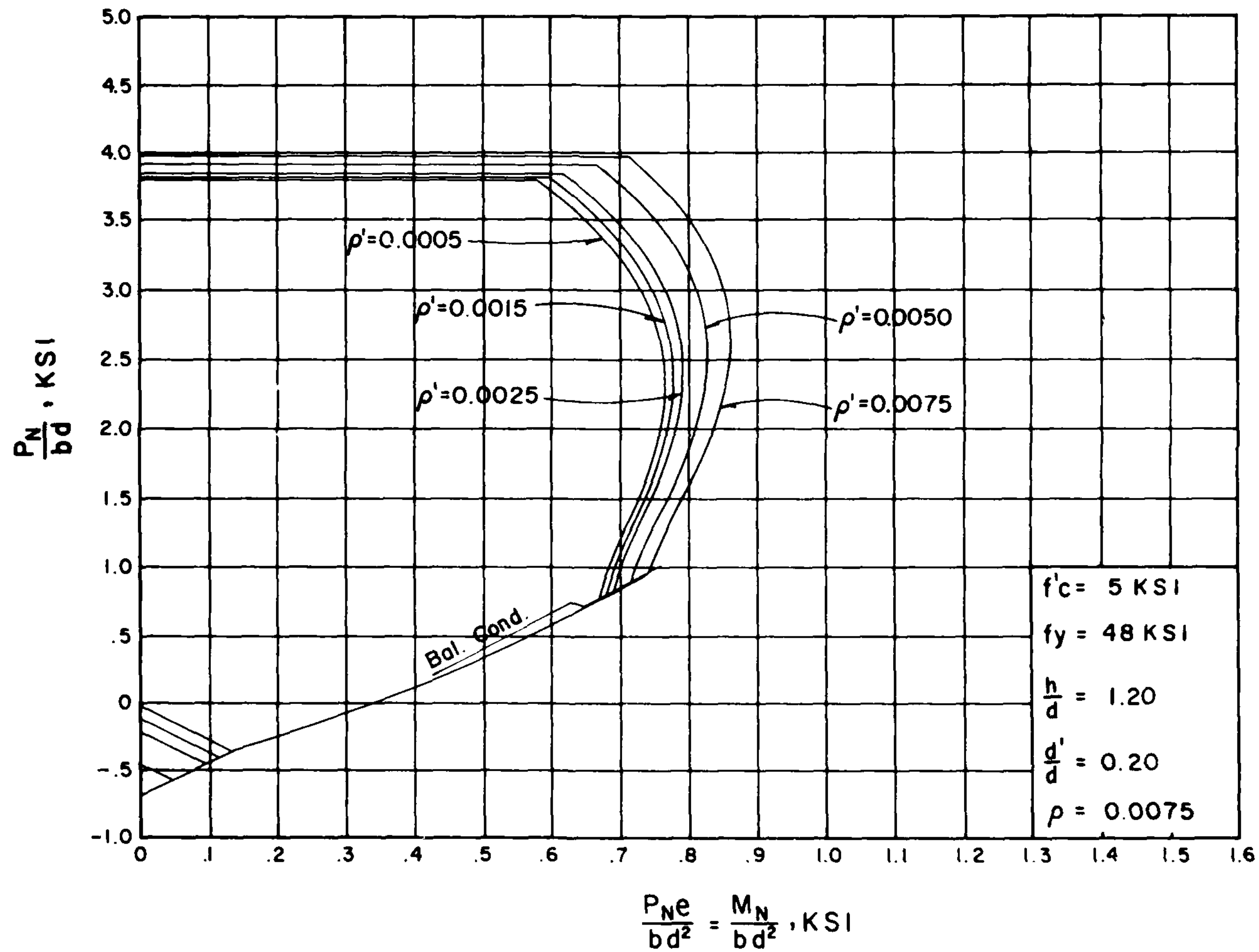


Figure 180. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0075)

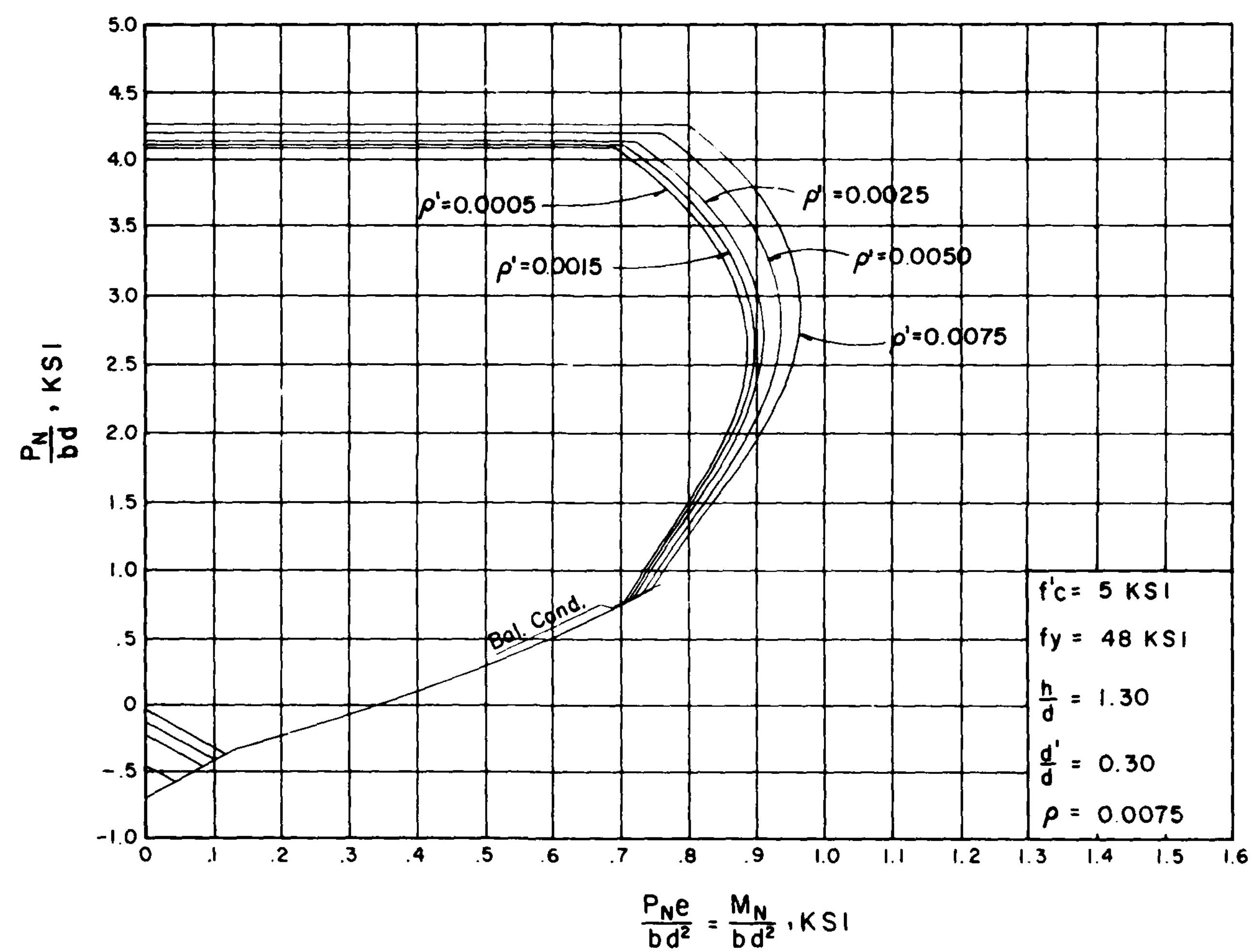


Figure 181. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0075)

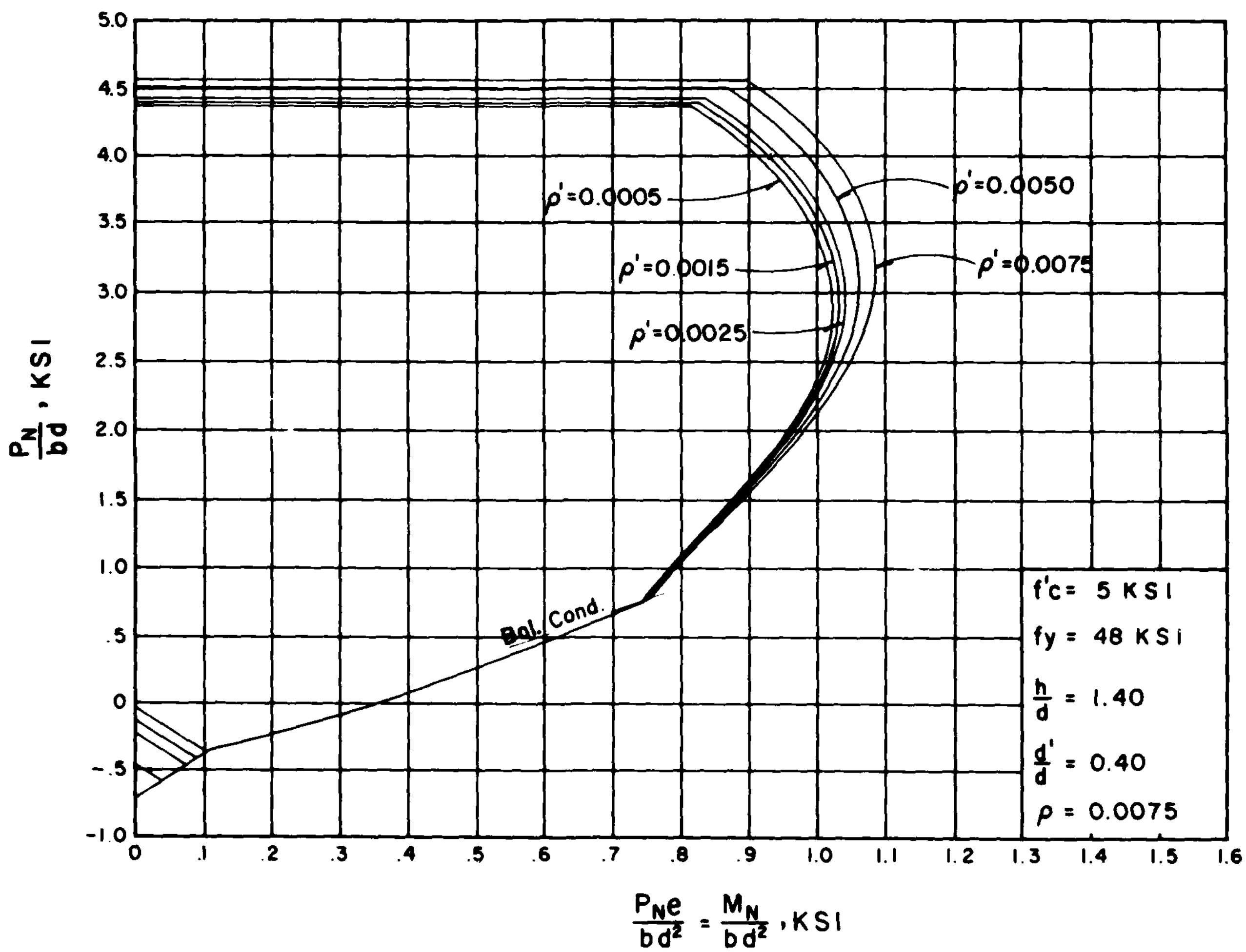


Figure 182. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0075)

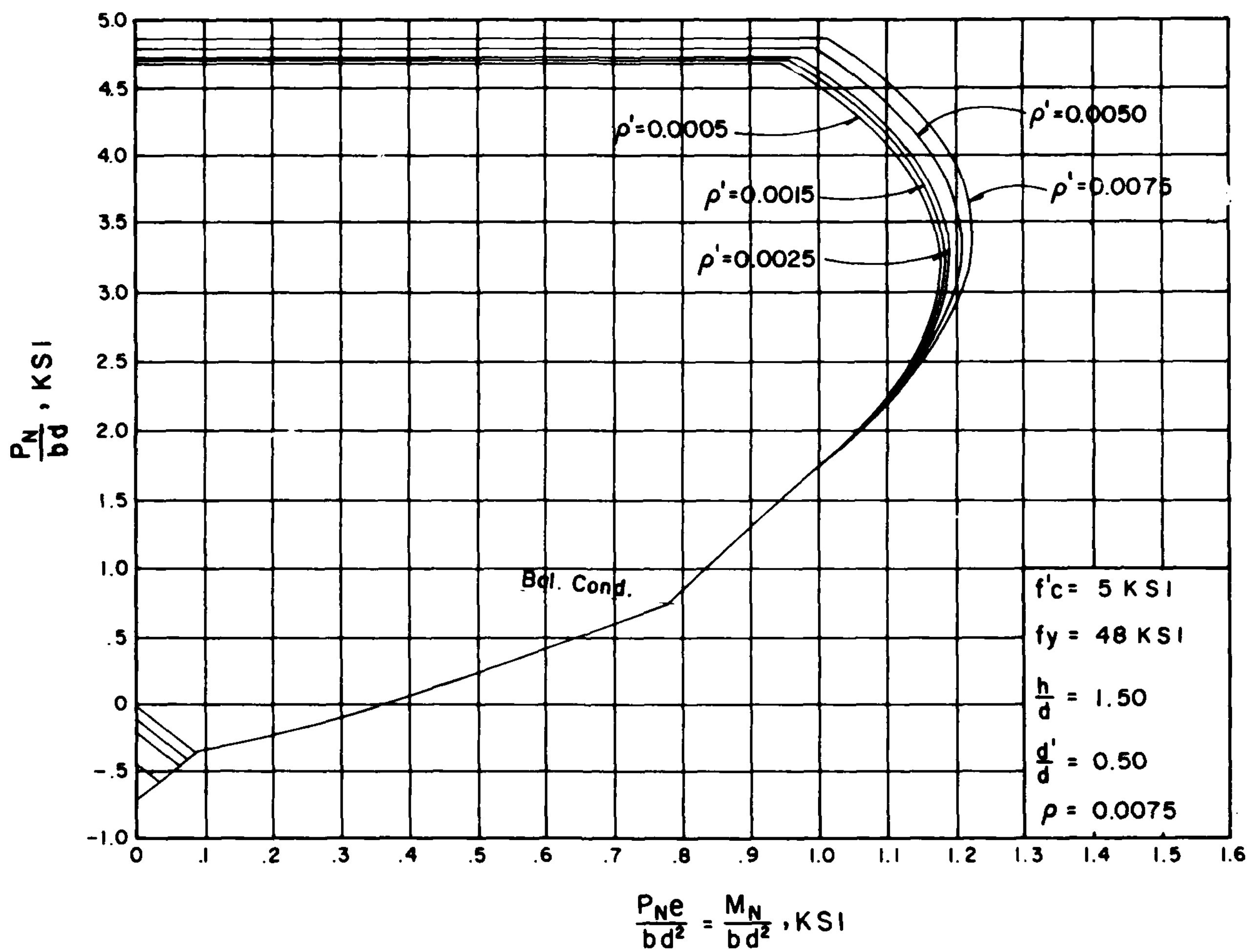


Figure 183. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0075)

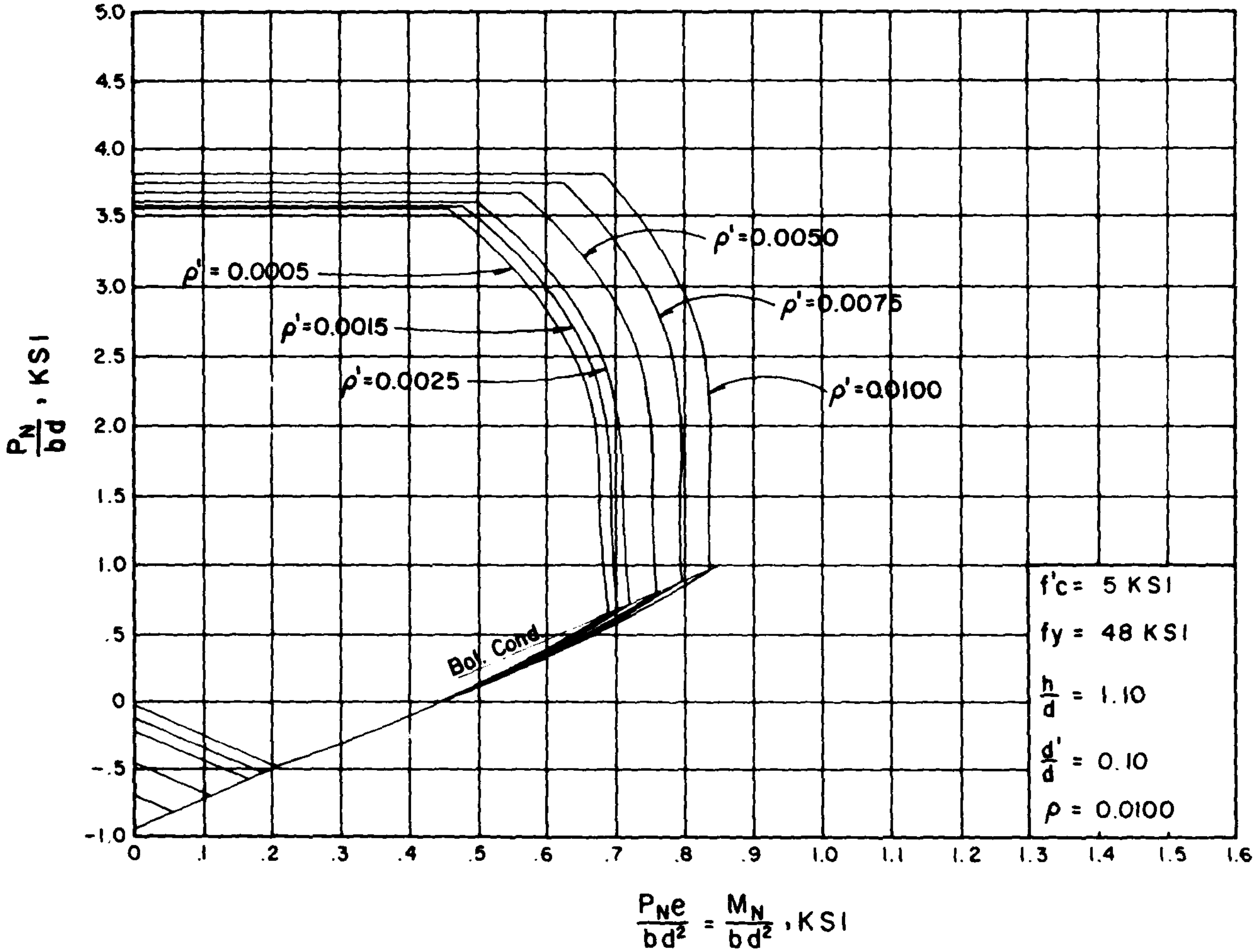


Figure 184. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.10, d'/d = 0.10, and ρ = 0.0100)

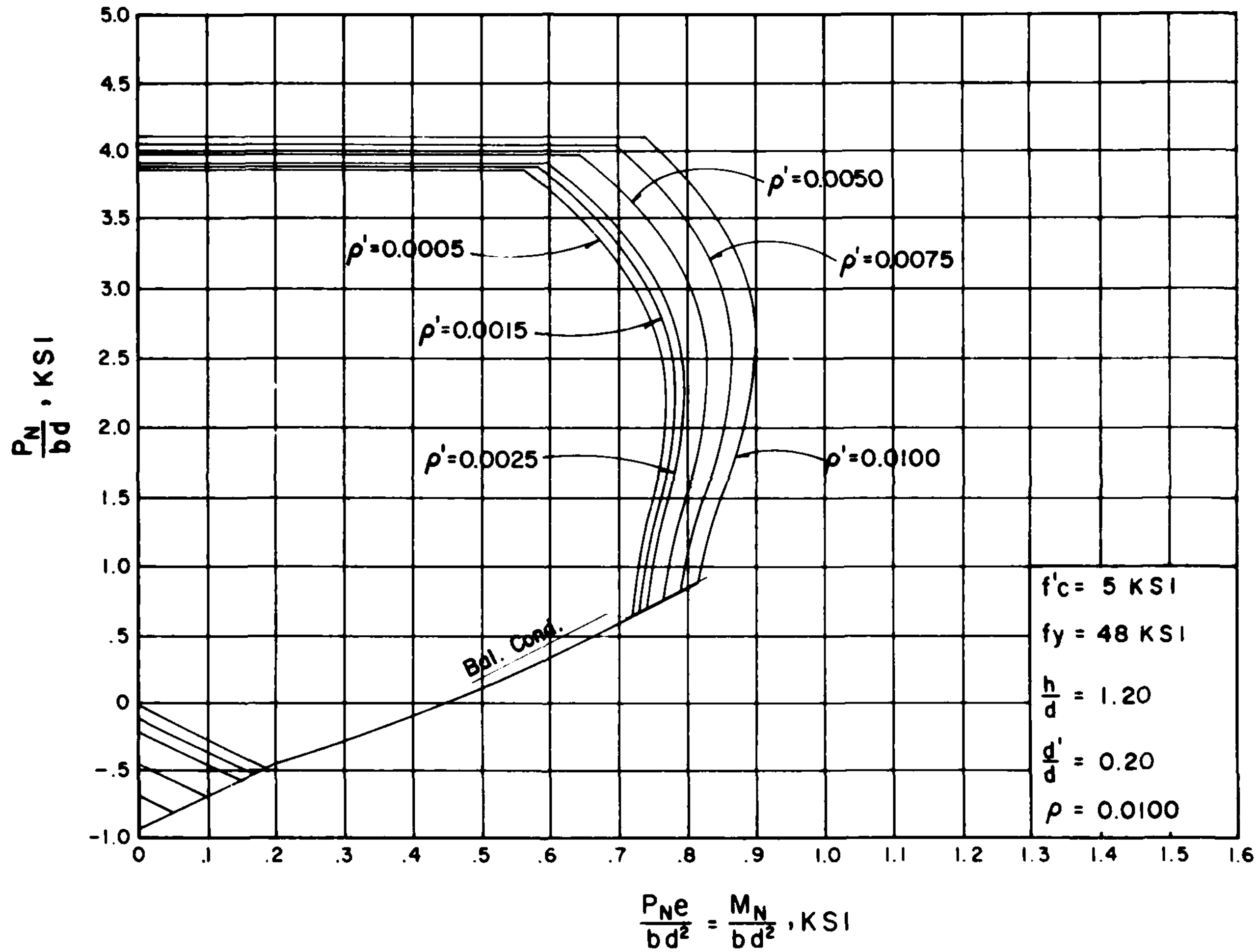


Figure 185. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.20, d'/d = 0.20, and ρ = 0.0100)

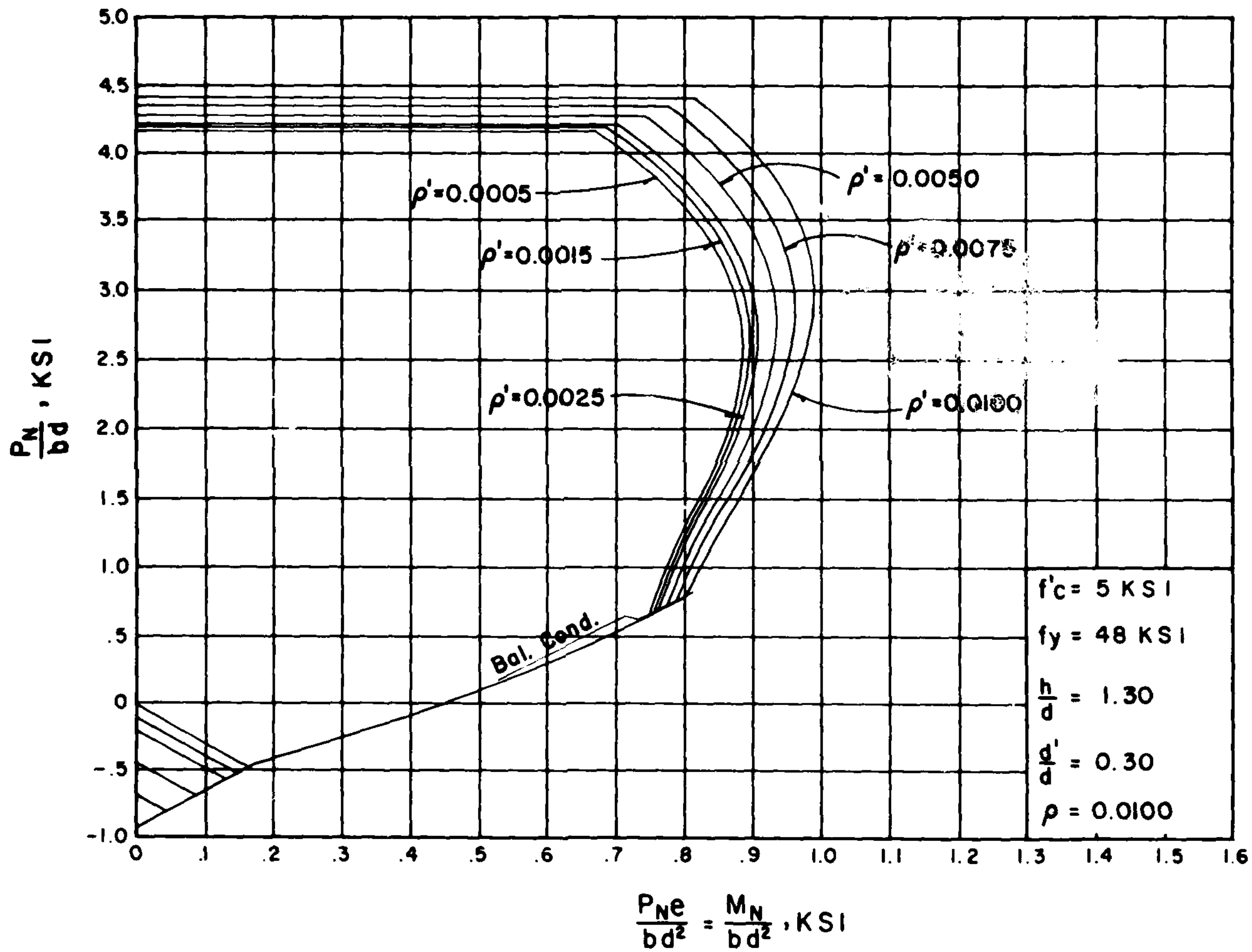


Figure 186. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.30, d'/d = 0.30, and ρ = 0.0100)

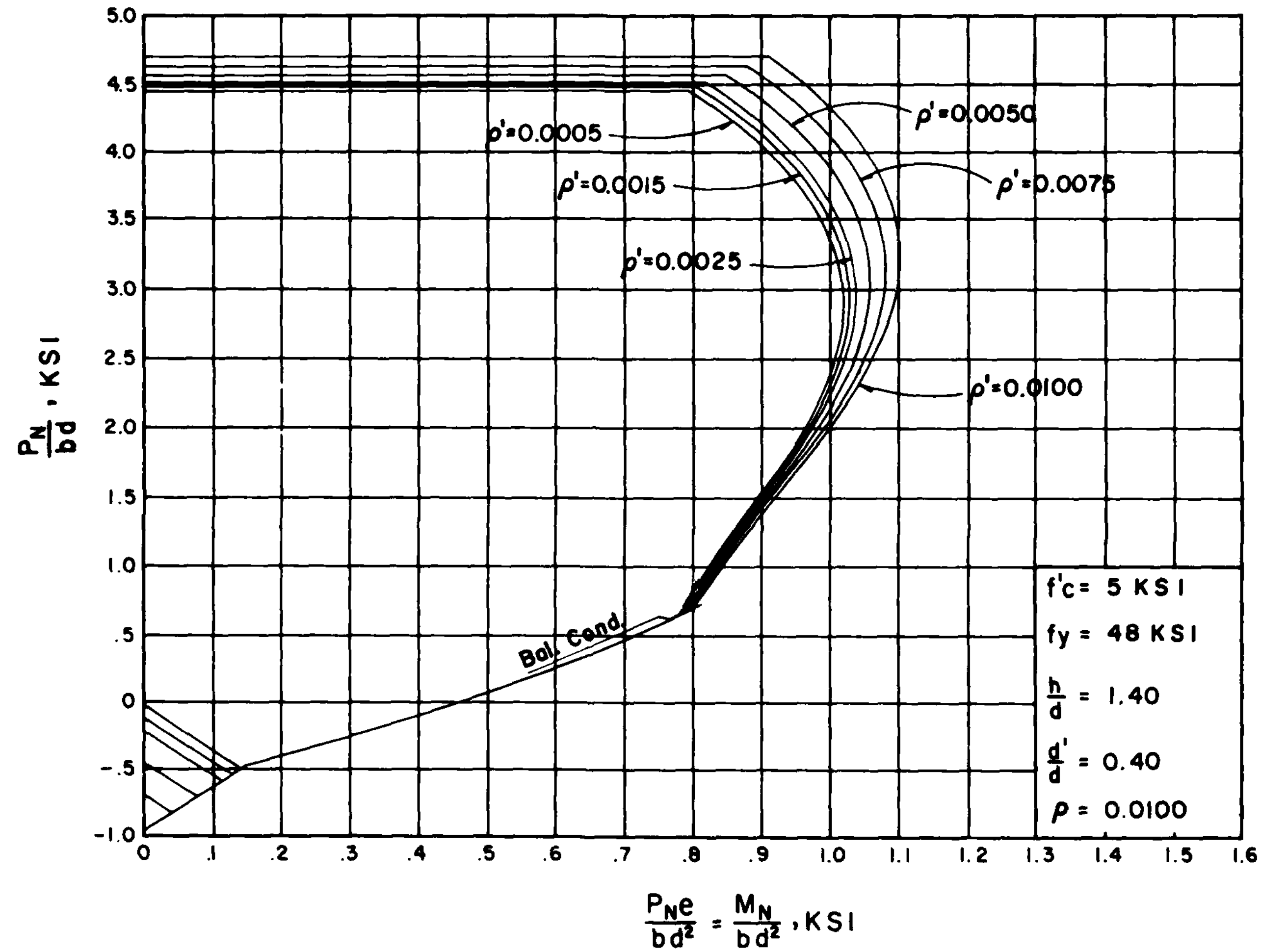


Figure 187. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.40, d'/d = 0.40, and ρ = 0.0100)

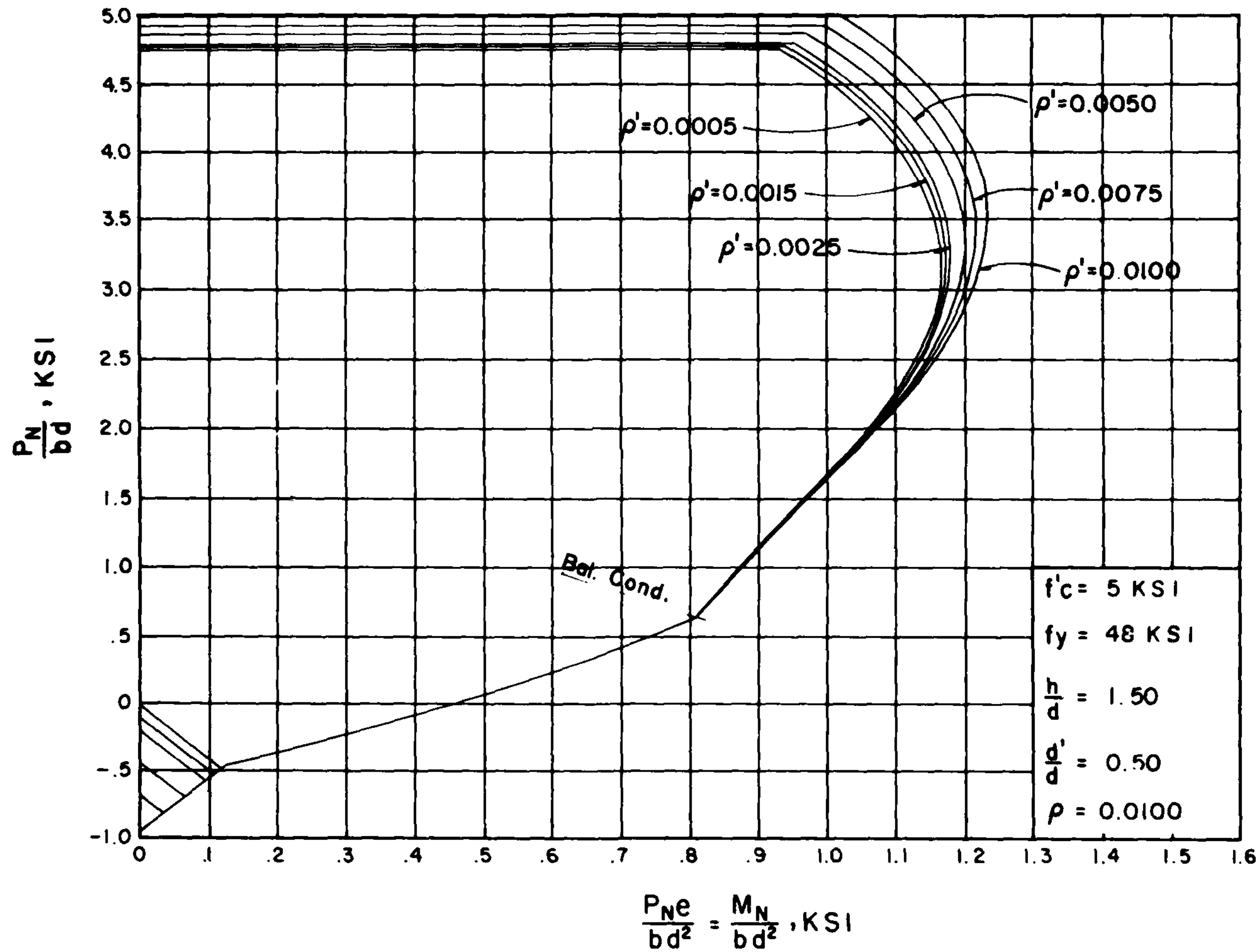


Figure 188. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.50, d'/d = 0.50, and ρ = 0.0100)

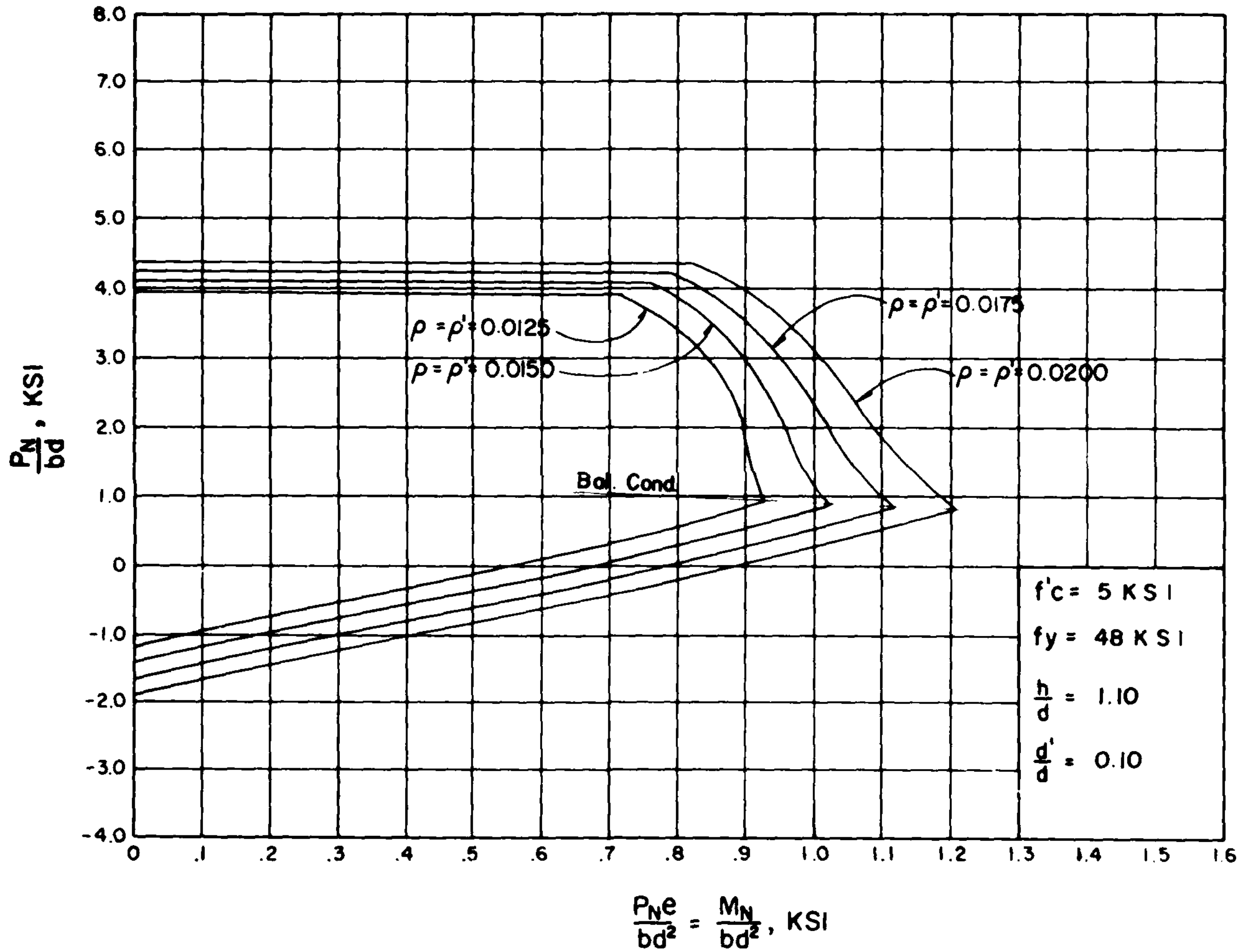


Figure 189. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.10, and d'/d = 0.10)

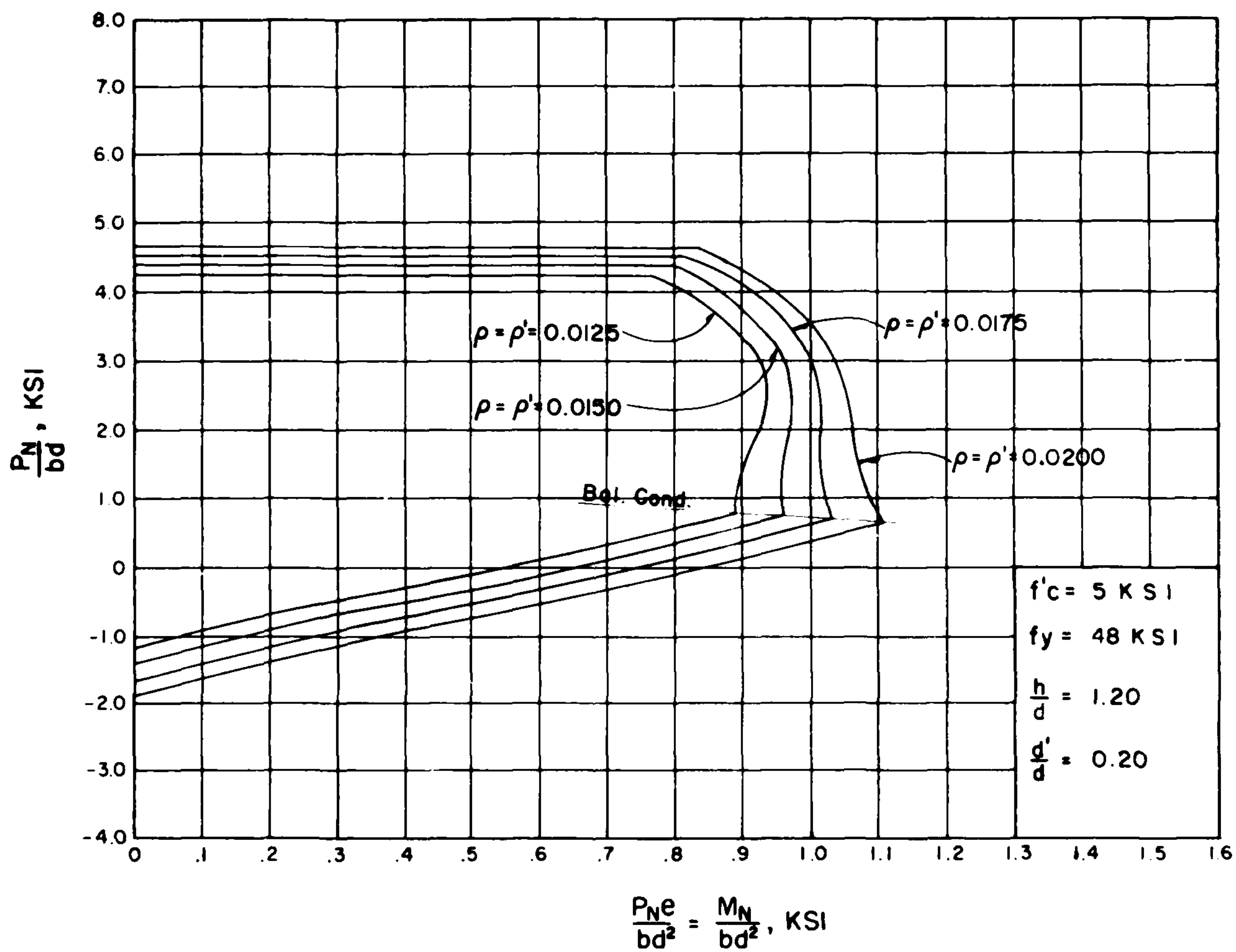


Figure 190. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.20, and d'/d = 0.20)

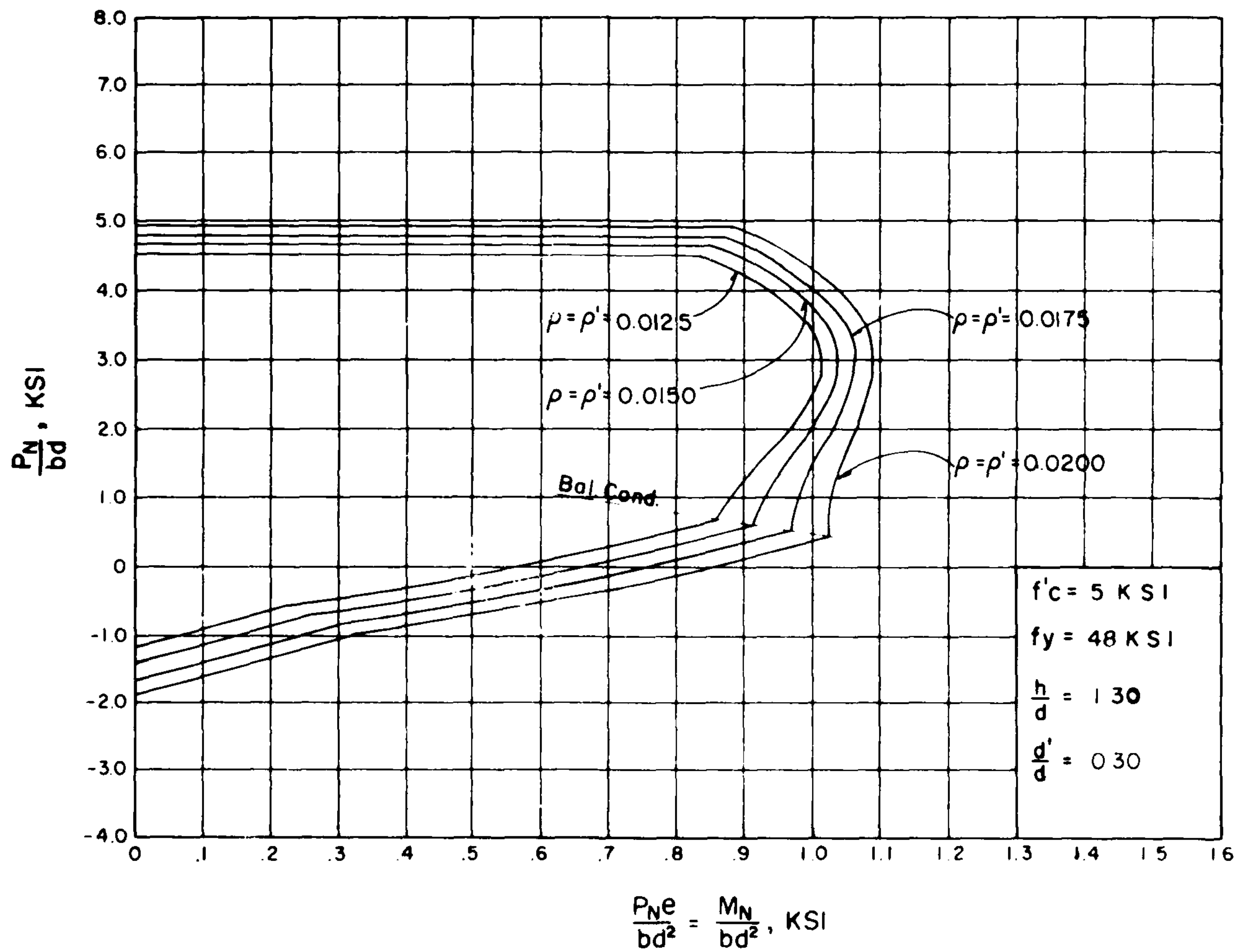


Figure 191. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.30, and d'/d = 0.30)

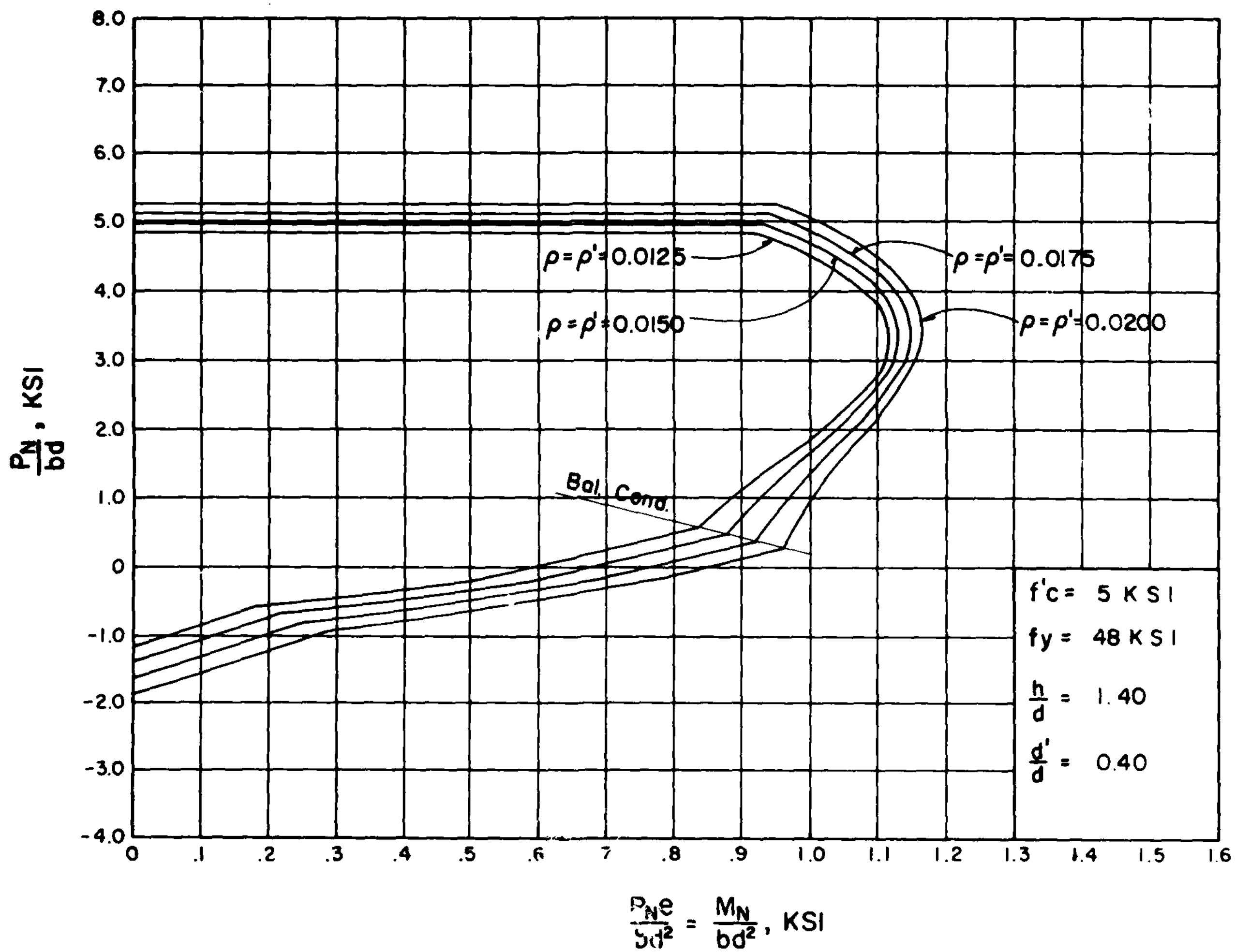


Figure 192. Load-moment strength inte:::tion diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ks.. h/d = 1.40, and d'/d = 0.40)

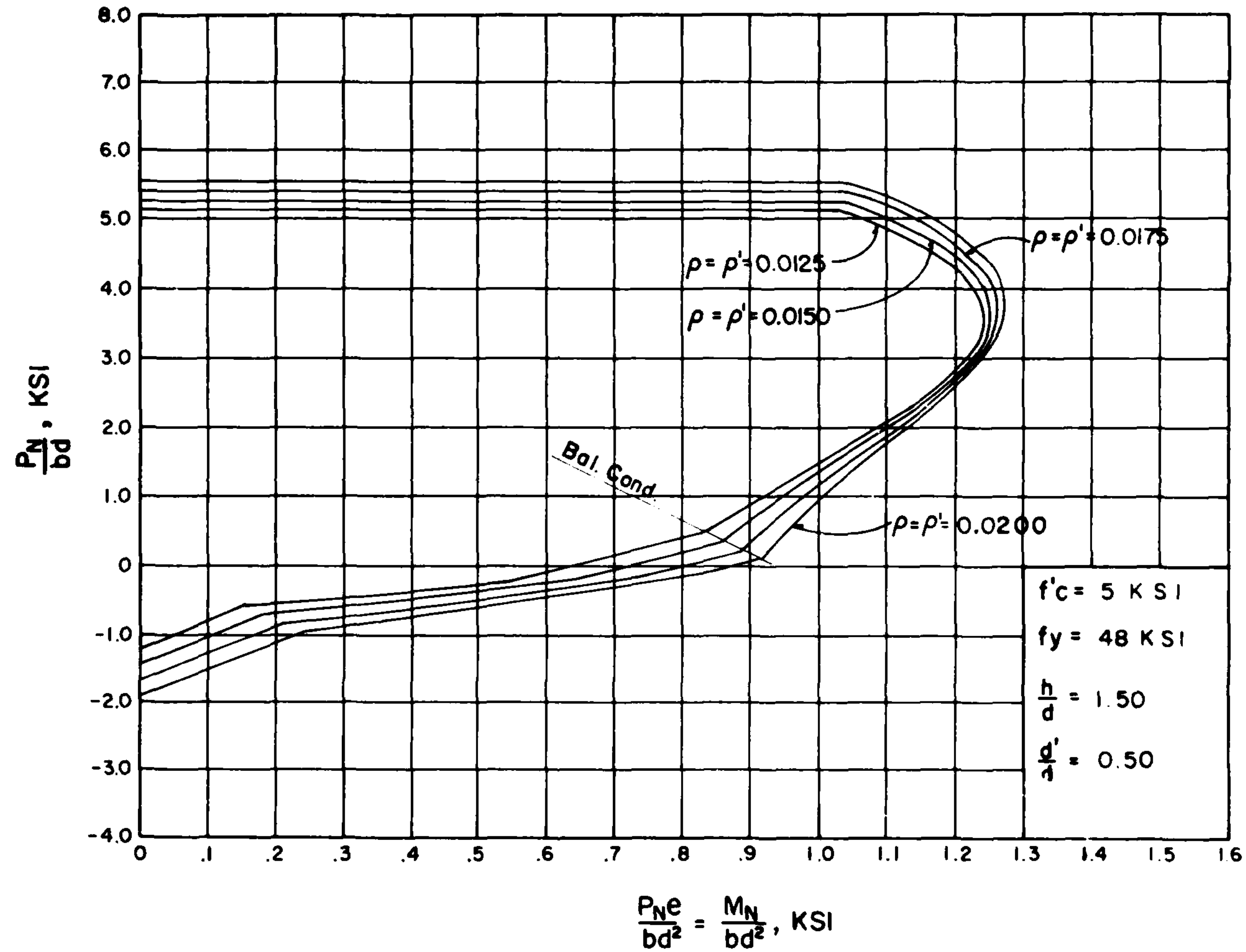


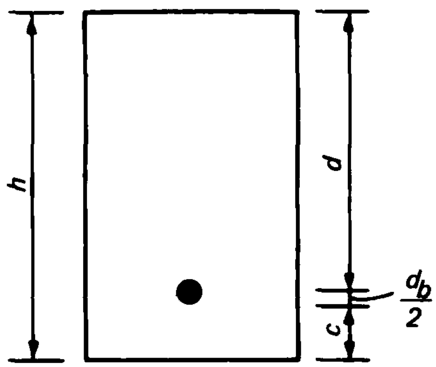
Figure 193. Load-moment strength interaction diagram for double reinforced members (f'_c = 5 ksi, f_y = 48 ksi, h/d = 1.50, and d'/d = 0.50)

APPENDIX A: COMMENTARY

1. The considerations and background information used in developing the design aids are discussed as follows.

Values of h/d

2. Tables 1 through 9 tabulate the h/d values which are needed to select appropriate load-moment strength interaction diagrams. From the sketch below, it can be shown that



$$h = d + \frac{d_b}{2} + c \tag{1}$$

where

- h = overall thickness of member
- d = distance from extreme compression fiber to centroid of tension reinforcement
- d_b = nominal diameter of tension reinforcement
- c = clear concrete cover

3. Dividing both sides of Equation 1 by d, one has

$$\frac{h}{d} = 1 + \frac{d_b + 2c}{2d} \tag{2}$$

From Equation 1,

$$d = h - \frac{d_b}{2} - c \tag{3}$$

Substituting Equation 3 into Equation 2,

$$\frac{h}{d} = 1 + \frac{d_b + 2c}{2h - d_b - 2c} \tag{4}$$

Tables 1 through 9 were calculated using Equation 4 for the most practical bar sizes and concrete covers for hydraulic structures.

Strength Reduction Factor

4. Figure 1 plots the strength reduction factor ϕ versus $P_u/f'_c bh$. According to ACI 318-77,* the ϕ may be increased from that for compression members to the 0.9 value permitted for flexure as the design axial load strength ϕP_n decreases from a specified value to zero. The value selected by ACI 318-77 was $0.10\ f'_c A_g$, which may be used for sections with symmetrical reinforcement provided f_y does not exceed 60,000 psi and the distance γh (distance between A_s and A'_s) is not less than $0.7h$. For other conditions, P_b must be calculated in accordance with ACI 318-77 to determine the upper value of design axial load strength ϕP_n (less of $0.10\ f'_c A_g$ or ϕP_b) below which an increase in ϕ can be made. For hydraulic structures, with $\rho < 0.25\rho_b$, the value of $0.10\ f'_c A_g$ is generally smaller than ϕP_b and computation of P_b is unnecessary. Therefore, for hydraulic structures, the strength reduction factor can be expressed as

$$\phi = 0.9 - \frac{2.0\ \phi P_N}{f'_c A_g} \tag{5}$$

Equation 5 can be rewritten as

---

* American Concrete Institute. 1977. "Building Code Requirements for Reinforced Concrete," ACI 318-77, Detroit, Mich., hereinafter referred to as ACI 318-77.

$$\phi = 0.9 - 2.0 \frac{P_u}{f'_c bh} \tag{6}$$

Figure 1 was plotted from Equation 6 with a lower limit of $\phi = 0.70$.

Interaction Diagrams

5. The capacity of reinforced concrete members subjected to combined flexure and axial load traditionally has been described by plots drawn as interaction diagrams on which axial strength versus moment strength is plotted for various percentages of steel. Each interaction diagram in Figures 3 through 32 relates values of (a) nominal axial stress P_N/bd , (b) nominal moment index $P_N e/bd^2$ or M_N/bd^2 , (c) ratio of e/d , and (d) reinforcement ratio ρ . When any two of these values are known, the other two values can be determined by using the interaction diagram(s) appropriate to f'_c , f_y , and h/d values, as illustrated in Part II.

6. The interaction diagrams presented in this report were calculated in accordance with the strength design method presented in Liu.*

a. Design assumptions and general requirements.

(1) Maximum usable strain ε_C at extreme concrete compression fiber should be assumed equal to 0.003. The allowable strain ε_M at extreme concrete compression fiber should be limited to $0.5\ \varepsilon_C$ for hydraulic structures.

(2) Balanced conditions exist at a cross section when the tension reinforcement reaches the strain corresponding to its specified yield strength f_y just as concrete in compression reaches its assumed allowable strain ε_M .

(3) Concrete stress of $0.85\ f'_c$ should be assumed uniformly distributed over an equivalent compression zone

---

* Tony C. Liu. "Strength Design of Reinforced Concrete Hydraulic Structures; T-Wall Design" (in preparation), Technical Report SL-80-4, Report 3, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

bounded by edges of the cross section and a straight line located parallel to the neutral axis at a distance $a = \beta_M C$ from the fiber of maximum compressive strain.

(4) Factor β_M should be taken as 0.55 for concrete strengths f'_c up to and including 4000 psi. For strengths above 4000 psi, β_M should be reduced continuously at a rate of 0.05 for each 1000 psi of strength in excess of 4000 psi, but β_M should not be taken less than 0.50.

(5) The eccentricity ratio e'/d should be defined as

$$\frac{e'}{d} = \frac{\frac{M_u}{P_u} + \left(d - \frac{h}{2}\right)}{d} \qquad (7)$$

where

e' is the eccentricity of axial load measured from the centroid of the tension reinforcement

P_u is considered positive for compression and negative for tension

b. <u>Flexural and compressive capacity--tension reinforcement only.</u>

(1) The design axial load strength ϕP_N of compression members should not be taken greater than the following:

(a) Grade 40 steel

$$\phi P_{N(max)} = 0.70\ \phi[0.85\ f'_c(A_g - \rho bd) + f_y \rho bd] \qquad (8)$$

(b) Grade 60 steel

$$\phi P_{N(max)} = 0.70\ \phi[0.85\ f'_c(A_g - \rho bd) + E_s \varepsilon_M \rho bd] \qquad (8a)$$

(2) The strength of a cross section is controlled by compression if the load has an eccentricity ratio e'/d no greater than that given by Equation 9 and by tension if e'/d exceeds this value.

$$\frac{e'_b}{d} = \frac{2k_b - k_b^2}{2k_b - \frac{f_y \rho}{0.425\ f'_c}} \qquad (9)$$

where

$$k_b = \frac{\beta_M E_s \varepsilon_M}{E_s \varepsilon_M + f_y} \qquad (10)$$

(3) Sections controlled by tension should be computed by

$$\phi P_N = \phi(0.85\ f'_c k_u bd - f_y \rho bd) \qquad (11)$$

and

$$\phi M_N = \phi(0.85\ f'_c k_u bd - f_y \rho bd)\left[\frac{e'}{d} - \left(1 - \frac{h}{2d}\right)\right]d \qquad (12)$$

where k_u should be determined from the following equation:

$$k_u^2 + 2\left(\frac{e'}{d} - 1\right)k_u - \frac{f_y \rho e'}{0.425\ f'_c d} \qquad (13)$$

(4) Sections controlled by compression should be computed by

$$\phi P_N = \phi(0.85\ f'_c k_u bd - f_{su} \rho bd) \qquad (14)$$

and

$$\phi M_N = \phi(0.85\ f'_c k_u bd - f_{su} \rho bd)\left[\frac{e'}{d} - \left(1 - \frac{h}{2d}\right)\right]d \qquad (15)$$

where

$$f_{su} = \frac{E_s \varepsilon_M (\beta_M - k_u)}{k_u} \qquad (16)$$

and k_u should be determined from the following equation:

$$k_u^3 + 2\left(\frac{e'}{d} - 1\right) k_u^2 + \left(\frac{E_s \varepsilon_M \rho e'}{0.425\ f'_c d}\right)k_u - \left(\frac{\beta_M E_s \varepsilon_M}{0.425\ f'_c}\right)\left(\frac{\rho e'}{d}\right) = 0 \qquad (17)$$

(5) The balanced load and moment should be computed using Equations 11 and 12 with $k_u = k_b$ and $e'/d = e'_b/d$.

The e_b'/d and k_b are given by Equations 9 and 10, respectively.

c. Flexural and compression capacity--tension and compression reinforcement.*

(1) The design axial load strength ϕP_N of compression members should not be taken greater than the following:

(a) Grade 40 steel

$$\phi P_{N(max)} = 0.70\ \phi\{0.85\ f_c'\ [A_g - (\rho + \rho')]bd + f_y(\rho + \rho')bd\} \quad (18a)$$

(b) Grade 60 steel

$$\phi P_{N(max)} = 0.70\ \phi\{0.85\ f_c'\ [A_g - (\rho + \rho')]bd + E_s\varepsilon_M(\rho + \rho')bd\} \quad (18b)$$

(2) The strength of a cross section is controlled by compression if the load has an eccentricity ratio e'/d no greater than that given by Equation 19 and by tension if e'/d exceeds this value.

$$\frac{e_b'}{d} = \frac{2k_b - k_b^2 + \dfrac{f_{su}'\rho'\left(1 - \dfrac{d'}{d}\right)}{0.425\ f_c'}}{2k_b - \dfrac{f_y\rho}{0.425\ f_c'} + \dfrac{f_{su}'\rho'}{0.425\ f_c'}} \quad (19)$$

where k_b is given in Equation 10 and f_{su}' is given in Equation 23 with $k_u = k_b$.

(3) Sections controlled by tension are computed by Equations 20, 21, and 23 with $f_{su} = f_y$.

(4) Sections controlled by compression should be computed by

$$\phi P_N = \phi(0.85\ f_c'k_u bd + f_{su}'\rho' bd - f_{su}\rho bd) \quad (20)$$

and

* Ties and stirrups should be provided where compression reinforcement is used.

$$\phi M_N = \phi(0.85\ f'_c k_u bd + f'_{su}\rho' bd - f_{su}\rho bd)\left[\frac{e'}{d} - \left(1 - \frac{h}{2d}\right)\right]d \tag{21}$$

where

$$f_{su} = \frac{E_s \varepsilon_M(\beta_1 - k_u)}{k_u} \geq -f_y \tag{22}$$

$$f'_{su} = \frac{E_s \varepsilon_M\left[k_u - \beta_1\left(\frac{d'}{d}\right)\right]}{k_u} \leq f_y \tag{23}$$

and k_u should be determined from the following equation:

$$k_u^3 + 2\left(\frac{e'}{d} - 1\right)k_u^2 + \frac{E_s \varepsilon_M}{0.425\ f'_c}\left[(\rho + \rho')\left(\frac{e'}{d}\right) - \rho'\left(1 - \frac{d'}{d}\right)\right]k_u - \frac{\beta_M E_s \varepsilon_M}{0.425\ f'_c}\left[\rho\left(\frac{d'}{d}\right)\left(\frac{e'}{d} + \frac{d'}{d} - 1\right) + \rho\left(\frac{e'}{d}\right)\right] = 0 \tag{24}$$

(5) The balanced load and moment should be computed using Equations 20-23 with $k_u = k_b$ and $e'/d = e'_b/d$. The e'_b/d and k_b are given by Equations 19 and 10, respectively.

d. Flexural and tension capacity.

(1) If the load has an eccentricity ratio $e'/d < 0$, the ϕP_N and ϕM_N should be computed by Equations 11-13 disregarding the compression reinforcement, if any.

(2) If the load has an eccentricity ratio $1 - h/2d \geq e'/d \geq 0$, reinforcement should be provided in both faces of the member in the following amount.

$$A_s = \frac{P_u(d - d' - e')}{\phi f_y(d - d')} \tag{25}$$

and

$$A'_s = \frac{P_u e'}{\phi f_y (d - d')} \tag{26}$$

7. The limits for positive and negative values of e/d are given in the interaction diagrams (Figures 2 and 32). The positive limit of e/d represents the point at which the stress in tension reinforcement is zero. When the positive value of e/d is less than this limit, the stress in steel changes from tension to compression, and double reinforced members should be used. The negative limit of e/d represents the point at which the axial tensile load is applied at the tension reinforcement. When the negative value of e/d is greater than this limit, the applied tensile load lies between the tension reinforcement and the centroid of the section. In this case, double reinforcement members should be used. The required steel areas should be calculated in accordance with Equations 25 and 26.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Liu, Tony C.
Strength design of reinforced concrete hydraulic structures : Report 2 : Design aids for use in the design and analysis of reinforced concrete hydraulic structural members subjected to combined flexure and axial loads / by Tony C. Liu and Scott Gleason (Structures Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1981.
225 p. in various pagings : ill. ; 27 cm. -- (Technical report ; SL-80-4, Report 2)
Cover title.
"December 1981."
"Prepared for Office, Chief of Engineers, U.S. Army under CWIS 31623."

1. Concrete--Testing. 2. Design. 3. Hydraulic structures. 4. Reinforced concrete. I. Gleason, Scott. II. United States. Army. Corps of Engineers.

Liu, Tony C.
Strength design of reinforced concrete hydraulic : ... 1981.
(Card 2)

Office of the Chief of Engineers. III. U.S. Army Engineer Waterways Experiment Station. Structures Laboratory. IV. Title V. Series: Technical report (U.S. Army Engineer Waterways Experiment Station); SL-80-4, Report 2.
TA7.W34 no.SL-80-4 Report 2

END

DATE
FILMED

3-82

DTIC